A BOTANICAL STUDY OF PASTURE MIXTURES

Walter Charles Stone

Department of Field Crops

University of Alberta

April, 1934

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A THESIS

submitted to the University of Alberta
in partial fulfilment of the requirements for
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MASTER OF SCIENCE

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Walter C. Stone

INTRODUCTION

Northern Alberta is essentially a mixed farming area. This fact has been entirely overlooked in the frenzy of breaking up all arable land for the growing of wheat. This has resulted in the rapid reduction in the acreage of natural grazing lands. Now that a virtual embargo has been placed on wheat production, a certain amount of this land will become available for seeding down to pasture. It was with this prospect in view that a pasture investigation was begun in 1931, the object being (1) to follow the changes in the botanical composition of certain pasture mixtures, (2) to note the effect of inter-specific competition, (3) to test the relative productivity of these mixtures, and (4) to test the longevity, drought resistance, palatability and winter hardiness of the constituent grasses and legumes. The mixtures were seeded in the same year on the University Farm by the Department of Animal Husbandry. This

[Livestock

[illegible]

department has kindly allowed the observations to be made which are reported herein.

LITERATURE REVIEW

Literature on botanical studies of pastures in general is very copious. Therefore, a review of reports dealing more particularly with botanical changes in and productivity of cultivated unfertilized pastures only will be attempted. Botanical studies of the effect of grazing on the pasture sward will first be reviewed. This will be followed by brief reference to literature dealing more particularly with effects of defoliation treatments on the botanical composition. Finally, literature relative to productivity of pastures under different systems of management will briefly be reviewed.

Botanical Composition of Pastures and Effects of Grazing

The literature on the botanical composition of unfertilized cultivated pastures is mainly of European origin; a few investigations of this kind, however, are reported from the United States.

Marshall, as early as 1788 and 1791, is reported by Griffiths and Phillips (20) to have described the botanical composition of certain old English pastures, and to have recommended rotational grazing, destruction of encroaching weeds and clipping of the herbage to prevent it becoming stemmy and going to seed. Curtis (1812) is reported by the same workers to have conceived the idea of using turfs from pastures for botanical analysis in studies of changes in the composition of the herbage. He found the dominant species in certain old English pastures to be those of Festuca and Agrostis. Fream (17, 18), who also employed the "turf method" of analysis, found that some good sixty-year-old British pastures consisted of 70 percent gramineous herbage and 25 percent leguminous herbage, and the rest a miscellaneous assortment of species of minor importance. The dominant species were perennial rye grass (Lolium perenne) and wild white clover (Trifolium repens). Carruthers (1890), as reported by Jones (24), checked Fream's work on a larger scale and found that rye grass was reduced in all cases to small proportions and its place taken by stronger growing grasses such as Orchard grass (Dactylis glomerata), Holcus spp. and Agrostis spp. This is contrary to Fream's results, and can only be explained by the probable varying conditions of the experiments.

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Armstrong (2) compared the botanical composition of good, medium and inferior old pastures with excellent recently laid down pastures in England. In the first-rate old pastures wild white clover and perennial rye grass were by far the most abundant species with orchard grass (Dactylis glomerata) third and bent (Agrostis alba) fourth in abundance. In the excellent new pastures the two former species again formed about two-thirds of the herbage, but orchard grass and rough-stalked meadow grass (Poa trivialis) were more abundant than in the older pastures. In the second-rate old pastures the proportion of wild white clover had diminished and perennial rye grass and other grasses and weeds had increased. In the inferior old pastures bent grasses and weeds occupied about 40 to 50 percent of the ground surface, rye grass and clovers took quite secondary places. Perennial rye grass occupied on the average only one-half and clovers only one-fifth of the proportion of the ground area which they covered in the best old pastures. Armstrong also found the choicest grazing land invariably associated with high rainfall and soils rich in available phosphates. Greater reliance may be placed on Armstrong's than on Fream's work, according to workers at Aberystwyth (5, 32) who point out that the turf method of analysis is more subject to variations than the "percentage area" method employed by Armstrong (2).

Edwards (6) studied the floristic changes of pastures at the University of Leeds and found Festuca spp., Agrostis vulgaris and Holcus lanatus predominating. These are undoubtedly slightly inferior types of pasture, as Fenton (10) found good Devon meadows high in perennial rye grass and wild white clover. In the badly treated pastures the poorer grasses such as the bromes (Bromus spp.), crested dog's tail (Cynosurus cristatus) and sweet vernal (Anthoxantum odoratum) predominated; this is in agreement with the earlier work reported from Cambridge by Armstrong. Fenton (11), in a further study of Devon pastures, found that heavier grazing tended to reduce the proportions of undesirable species and increase the growth of the more nutritious ones. It is pointed out that the pasture should not be allowed to grow up and produce seed, as the older fibrous growth would not be readily grazed by livestock. This latter view is strongly supported by Stapledon (37). In one of the permanent dairy pastures analysed by Fenton perennial rye grass covered 23 percent and wild white clover 16.2 percent of the total ground area. A good bull pasture is reported to have 28.3 percent of the area covered with perennial rye grass, 11.2 percent with orchard grass and 10.1 percent with wild white clover. Stapledon and Thomas (36) also report the need for regulated grazing under Welsh conditions, as revealed by

botanical analyses of the pasture herbages.

Fenton (14) reports further a study of the effect of grazing on the botanical composition of English pastures. His results, obtained by separating and weighing the quantities of each species present in the cut herbage, point to a definite seasonal periodicity in the fluctuations of the amounts of wild white clover and perennial rye grass (these two species formed 70 percent of the herbage). Early in the season rye grass was dominant, with bent next and clover beginning to grow. Later in the season, under the influence of pasturing, there was a gradual trend towards a more constant flora with rapid growth of wild white clover. At mid-summer the clover exceeded the rye grass. By the 23rd of August the situation was reversed, i.e., the rye grass had increased at the expense of the clover. Bent grass also showed a certain periodicity in that it was most abundant in the spring and fall. These results are confirmed by Levy and Madden (25) working in New Zealand, who also found a seasonal rise and fall in growth of the main pasture species. White clover was found to cover proportionately the greatest area in May and February, while the percentage area of suckling clover was greatest in August and November. Kentucky blue grass was present in greatest abundance in September, October and November.

Bare ground was most prevalent in November and December.

Fenton (12) investigated further, by means of cut samples, the changes in vegetation of pasture plots in Devonshire. He reports that the plots showed three phases in vegetation before a more stable flora was developed. The order of aggressiveness was, Italian rye grass, perennial rye grass, red clover and orchard grass followed by wild white clover, bent (Agrostis spp.), Poa trivialis, and, lastly, timothy (Phleum pratense), tall and meadow fescue. Alsike clover and timothy proved a failure and the rye grasses had a depressing effect on the fescues due to their superior drought resisting properties. Wild white clover also proved to be quite drought resistant, and formed, ecologically, an association with perennial rye grass. Weeds were kept well in check.

In a pasture survey carried out by Fenton (15) in Scotland it was found that where the rotational method of grazing was employed, there was a gradual increase in the wild white clover and perennial rye grass contents of the herbage with a decrease in the less desirable grasses, bent and rough-stalked meadow grass (Poa trivialis). This is in agreement with results reported by him from England in the same year (14). Similar observations were made by Hein and Vinall (22) in the United States and reported in 1933. Examination by Fenton of pastures of short duration

revealed some interesting facts. In the first-year stage perennial rye grass was dominant over the other grasses present, wild white clover plants were not very abundant, and bare areas of soil were numerous. In the second year wild white clover and orchard grass increased, however, and perennial rye grass, timothy and red clover decreased. Little change could be noted in the third year, except that wild white clover and perennial rye grass formed an association. This is also in agreement with results reported by him from England the previous year. The fourth year showed very little change from the third year. However, a decrease in perennial rye grass with a corresponding increase in Poa trivialis was noted. This decrease of perennial rye grass by the fourth year is also reported by Hein and Vinall (22), working in Maryland. They also point to the complete disappearance of meadow fescue, timothy, Italian rye grass and clover, followed by marked increases in Kentucky blue grass, red top and orchard grass under continuous grazing. In seventeen-year-old grasslands, Fenton found 70 percent wild white clover and 26 percent perennial rye grass. This is very striking in comparison with the results obtained by Hein and Vinall, which have already been referred to. Fenton's work finds further support in the work reported by Fink, Mortimer and Truog (16) from Wisconsin. They analysed

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permanent (20-year-old) pastures and found that the turf consisted largely of Kentucky blue grass with scattered plants of timothy, red top and white clover, and an abundance of weeds and bare areas.

Kentucky blue grass and wild white clover*, according to the literature, certainly appear to be the two hardiest and longest lived perennials for pasture purposes. This is not true of Dutch clover, however, as has been shown by Roberts and Jones (30) at Aberystwyth. These workers studied pasture establishment in Wales and found that Dutch clover** was very short lived in competition with grasses and other clovers in pasture mixtures, as compared to wild white clover. This is also pointed out in Miss Erith's monograph on this plant (8). In mixtures where red clover was included with wild white clover, Jones (23) observed that the former had a depressing effect on the latter. It was only as red clover died out that the wild white clover began to flourish and spread normally.

A very excellent substantiation of the work of Roberts and Jones is reported by Fenton (13), who investigated the carrying capacity of five pasture mixtures

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* Wild white clover is referred to, botanically, as Trifolium repens var. sylvestre.

** White Dutch clover is a cultivated strain of var. sylvestre referred to as race hollandicum (8).

** Alsike clover is a cultivated strain of T. hybridum recognized to be a race hollandicum (3).

in Devonshire. He points out that where drought is likely to occur, it is impossible to form a satisfactory pasture turf without wild white clover. He found Dutch clover of value in the mixture in the first year of grazing only, as in subsequent years it rapidly disappeared.

It appears from a review of results obtained by Stapledon and Thomas (36) that wild white clover is essentially a lowland plant. They report that lowland permanent pastures consisted predominantly of perennial rye grass, orchard grass and wild white clover, while in upland pastures bent and fine-leaved fescues predominated, and the leguminous flora was very meagre.

In parts of south and west Australia where the annual rainfall seldom exceeds 10 to 12 inches, Nelson (26) found Trifolium subterraneum and Lupinus pilosus very productive, and promising constituents of sheep pastures in those areas.

Blackman (3) reports a very interesting experiment from Jealott's Hill, Berkshire, England. He was able to show by means of tiller counts of plants in nine different pastures that severe grazing in the spring or autumn leads to a suppression of Lolium perenne, while light grazing at that time leads to an increase in this species. He also found severe early grazing unfavorable to Poa trivialis. However, light grazing, on the other hand, did not serve to increase it. Undergrazing during the mid-season favored development of Agrostis spp., but it was injurious

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[illegible] reports a very interesting experiment [illegible]. He was able to [illegible] of tiller counts of plants in nine different [illegible] that severe grazing [illegible] in a suppression of *Lolium perenne*, while light grazing at [illegible] leads to an increase in this species. He also [illegible] early grazing unfavorable to *Poa trivialis*, [illegible]

to Trifolium repens. Heavy grazing, on the other hand, at this time served to decrease these grasses and markedly increase T. repens. Since the Agrostis species are reported to be inferior in palatability to L. perenne, it might be inferred that heavy grazing, within limits, is more beneficial than harmful.

A similar result was obtained by Jones (24) who found that the botanical composition of a pasture sward altered with the management of the stock. Lolium perenne was encouraged by resting in the spring. Early summer grazing suppressed Dactylis glomerata (this species is reported to be a slow grower in the spring) and resting at this time encouraged it. The wild white clover was favored by keeping in check by means of early grazing its earlier and tall growing competitors. This, he points out, is in agreement with earlier results obtained by him. Similarly, botanical analyses revealed that L. perenne and D. glomerata were both strengthened by avoiding early autumn grazing. Late autumn rest had no appreciable effect on the latter species, but the former was markedly benefitted. Late or early autumn rest did not favor the growth of T. repens, but it did favor the growth of T. pratense.

The evidence presented so far is in support of the view that greater success is achieved with a mixture or mixtures consisting of a few well chosen species than

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with a mixture containing a multiplicity of species. This was conclusively demonstrated by Roberts and Jones (30) to be the case under Welsh conditions. A simple mixture including perennial rye grass (L. perenne) and wild white clover (T. repens) gave in every case the best results. Dutch clover (T. repens), as has already been pointed out, proved very short-lived and relatively unproductive on the longer leys.

Stapledon (37), working in Aberystwyth, reports that bent grass and wild white clover are the most difficult plants to kill out. Bent was found to stand more severe grazing than the clover or fine-leaved fescues. Indigenous perennial rye grass was found to stand up under heavy grazing better than timothy, orchard grass and Yorkshire fog (Holcus lanatus). Tall oat grass withstood heavy grazing poorly and is reported to be of no value under a system of heavy grazing. Sweet vernal (Anthoxantum odoratum) endured heavy grazing in order next to bent. Stapledon also reports that palatability of pasture plants is an important factor in maintaining a good stand. Grasses which were pubescent or scabrous were avoided by the stock to the detriment of the more palatable species. Timothy and Italian rye grass are reported to be more palatable; white clover coming next; then perennial rye grass; then orchard grass, meadow fescue and meadow foxtail; Yorkshire fog (Holcus lanatus) and bent; and lastly the fine-leaved

fescues. Close clipping will, he points out, make palatable practically any grass.

Productivity of Cultivated Pastures

The botanical composition of a pasture properly interpreted is usually an indication of its productivity and relative ability to produce highly nutritive herbage. If a pasture mixture is composed of inferior species possessing low yielding qualities, the resulting pasturage will be low in yield and poor in nutriment. If, on the other hand, seed mixtures are blended with the definite object of providing pasturage high in yield and quality, they will include such species as perennial rye grass, Kentucky blue grass, bent grass, orchard grass, wild white clover, red clover, alfalfa and other valuable species, depending upon the area and country in which the mixtures are to be grown.

In reviewing the literature on pasture productivity brief reference will also be made to results obtained in studies of the effect of systems of partial periodic defoliations.

Stapledon and Davies (35) report a falling off in pasture yield from year to year under a system of periodic defoliations by means of a lawn mower. Stapledon and Thomas (36) found monthly cuts with sheep shears not

markedly injurious to temporary pastures. More frequent defoliations, however, did result in a lowering of the productivity of the cut area and a thinning of the more productive species in the stand. This is in agreement with Könekamp and König (1929), who found, according to Jones (24), that mown grassland became dominated by D. glomerata and the grazed sward by L. perenne.

Levy and Madden (25), working in New Zealand, also studied the effect of continuous mowing. They found that, while this treatment greatly reduced the amount of bare ground and perennial rye grass present, it greatly increased the ground covered by Kentucky blue grass, timothy and wild white clover after periods of one and two years. A marked reduction was also observed in the case of brown top, sweet vernal and other less desirable grasses, indicating the beneficial effect of this method of treatment, with the exception of perennial rye grass which showed a decline.

Aldous (1) investigated the effect of clipping treatments on the yield of pasturage in Kansas and found that the yield varied inversely with the frequency of cutting. The proportion of valuable forage in the stand also decreased with frequency of cutting. From this result he concludes by analogy that continuous heavy grazing is bound to cause rapid deterioration of pasture

lands. His results are a conclusive verification of the earlier work of Ellet and Carrier (7) in the United States, Fagan (9) in Wales, and other earlier workers. Shutt et al (31) working at Ottawa, Canada, also obtained results in agreement with those of Aldous, namely that yield of dry matter decreased with frequency of cutting.

Roberts and Jones (30 and Roberts (28, 29) studied botanically the productivity of a number of pastures at the University of Bangor by means of percentage composition determinations by weight. They found perennial rye grass, orchard grass, timothy and meadow fescue to be present in greatest abundance in the cut herbage after the pasture had become thoroughly established. Similar results were obtained by Fenton (14) in a study of English pastures.

Wolfe (39) tested the yielding ability of a number of pasture mixtures in Virginia and found a mixture composed of Kentucky blue grass, orchard grass, red top and white clover to be a very desirable one from the standpoint of yield of both hay and of pasturage. He found that on the average the yield of pasturage was from 40 to 65 percent of the yield of hay. By including red clover in the mixture it was possible to increase materially the yield of pasturage the first two to three years. This is also a striking result reported from Wales by Jones (23). However, red clover is reported by the same investigator to have an undesirable effect on wild white clover, and for

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[illegible] of pasture mixtures in Virginia and found a mixture composed of Kentucky blue grass, orchard grass, red top and white clover to be a very desirable one from the standpoint of yield of both hay and of pasturage. He found that on the average the yield of meadows was from 65 to 85 percent of the yield of hay. [illegible] it was possible to increase materially the yield of [illegible] the first two to three years. This is also a [illegible] result reported from Wales by Jones (38). [illegible], red clover is reported by the same investigator to have an undesirable effect on wild white clover, and [illegible]

this reason it should be included sparingly in the mixture.

Fenton (12) determined the yield of pasturage by adding all the cuts taken throughout the season. On this basis he reports that a well-balanced mixture of rye grasses (Lolium spp.), red clover, orchard grass and wild white clover is very productive in England. If these cuts were continuous and too frequent, injury to the plants resulted followed by a depression in yield the following year. This depression in yield by increased frequency of cutting is reported in all the literature reviewed covering this point. In a later paper reported by Fenton (13) from Devonshire he points to the superiority in yield of a mixture containing the two rye grasses and wild white clover along with a small quantity of red clover to give bulk in the first two years. In an investigation reported from Scotland in the same year he points out that only one cutting of hay should be taken each season prior to grazing, as cutting more than one hay crop may have disastrous results in depressing and even killing the more important turf growing species (15).

Vinall and Hein (38) compared the seasonal productivity of a pasture mixture consisting of Kentucky blue grass, red top, timothy, orchard grass, meadow fescue, Italian and perennial rye grasses, the three clovers red, white and alsike, and Lespedeza sp. (presumably striata)

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[illegible] and [illegible] ([illegible]) [illegible] the [illegible] [illegible] of [illegible] [illegible] [illegible] of [illegible] grass, red top, [illegible], [illegible] [illegible], [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], and [illegible] sp. ([illegible] [illegible])

with Kentucky blue grass seeded alone. The mixture yielded a total of 1,794 pounds and Kentucky blue 1,033 pounds of dry matter per acre. The relatively low yield of the mixture is undoubtedly due largely to inter-specific competition. This has been clearly brought out in the European literature (12, 32, 33, 34).

Rigg and Askew (27) report that the total yield of dry matter from New Zealand dairy pastures was greatly reduced in dry seasons, which might be expected. This result is thoroughly substantiated by Fenton's work in Great Britain (12, 13, 15), and by Wolfe (39) and Vinall and Hein (38) in the United States.

PRE-EXPERIMENTAL PROCEDURE

Description of Project

Observations are reported on six pasture mixtures seeded on a rich black loam soil previously fallowed.

History of land. The land on which the mixtures were seeded had previously produced the following crops: mixture I, oats and several crops of sunflowers since breaking in 1922; mixture II, rape as well as grains in former years; mixture III, grain mixtures, alfalfa, rape and sunflowers in different years; mixture IV, turnips until 1926, oats from 1926 to 1930; mixtures V and VI,

grain mixtures, alfalfa, rape and sunflowers for hog runs in different years up to 1930. In 1930 all these areas were plowed and thoroughly cultivated from time to time to destroy weeds. The land was also thoroughly cultivated, harrowed and packed to ensure a good seed bed before seeding the pasture mixtures early in the summer of 1931.

Seed mixtures. The following are the mixtures seeded:

Pasture	Number of acres	Mixture	Pounds of seed per acre	Date of seeding
I	28	Brome grass	2.8	June 25
		Crested wheat grass	2.5	June 26
		Western rye grass	0.7	
		*Alfalfa	3.0	
		*Sweet clover	3.0	
		*Kentucky blue grass	3.0	
		*Alsike clover	2.0	
II	2.4	Western rye grass	5	June 29
		*Altaswede red clover	4	
		*Timothy grass	3	
		*Alsike clover	3	
III	1.5	*Alfalfa	5	July 7
		Brome grass	5	
		*Kentucky blue grass	4	
		*White Dutch clover	3	

* See method of seeding.

Pasture	Number of acres	Mixture	Pounds of seed per acre	Date of seeding
IV	3	Crested wheat grass	2	July 8
		Brome grass	2.7	
		*Kentucky blue grass	4	
		*White Dutch clover	5	
		*Sweet clover	3	
V	6.25	Crested wheat grass	5	June 27
		*Kentucky blue grass	4	
		*Alfalfa	3	
		*White Dutch clover	2	
VI	6.25	*Alfalfa	6	June 27
		Brome grass	7	

Description of seed. The quality and kinds of seed sown are as follows:

Sweet clover (Melilotus alba): White blossom, grade No. 1.

Alfalfa (Medicago media): Grimm, grade No. 1.

Altaswede red clover (Trifolium pratense): Certified, grade No. 1.

Alsike clover (T. hybridum): Certified, grade No. 1.

White Dutch clover (T. repens var. sylvestre race hollandicum): Certified, grade No. 1.

* See method of seeding.

Brome grass (Bromus inermis): Certified, couch-free, grade No. 1.

Kentucky blue grass (Poa pratensis): Grade No. 1.

Timothy (Phleum pratense): Grade No. 1.

Western rye grass (Agropyron tenerum): Certified couch-free, grade No. 1.

Crested wheat grass (A. cristatum): Certified couch-free, grade No. 1.

The seeds were purchased in Edmonton from reputable seed firms.

Method of seeding. Small seeds* were mixed and the mixture seeded through a grass-seeder attachment on the front of a disc grain drill, the seeds falling into the openings made by the discs. The other seeds were seeded broadcast by hand and covered by harrowing. All the pastures except one were seeded in one direction only. Pasture II, however, was seeded in two directions: half the seed lengthwise and half the seed crosswise of the area.

After Management

No definite scheme of pasture management was followed, as this phase was not under the writer's direction. Weedy patches appearing in the pastures were clipped with a

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* The small-seeded species are: sweet clover, Alsike clover, Altaswede red clover, white Dutch clover, alfalfa, Kentucky blue grass and timothy grass.

mower at intervals by the Animal Husbandry Department the first season to prevent the weeds going to seed and smothering the young pasture growth. All the pastures, except IV, were grazed by cattle the first fall because of the excessive growth during an unusually moist season. In 1932 grazing was commenced the last week in May on all the pastures, except III and IV, which were cut for hay the second week in July, and continued until fall (Pasture I was rested for two weeks in July). Pastures III and IV after cutting were grazed continuously until fall the same as the rest, III by cattle and IV by sheep. Pasture I, after the two weeks rest period in July, was cut for hay. It was then pastured again by cattle. In 1933 all the pastures were grazed continuously from the last week in May until fall, I, II, III and V by cattle and IV by brood mares and colts. No other treatments were given these pastures.

EXPERIMENTAL PROCEDURE

Methods were devised for studying the effect of grazing and clipping treatments, the effect of inter-specific competition, the extent of winter injury, and the relative productivity of the various mixtures.

[illegible] going to seed and smothering the young [illegible] growth. [illegible] the first year because of the excessive growth [illegible]. In 1932 grazing was [illegible] the first week in May in all the pastures, except III and IV, which were cut for hay the second week in June, and continued until fall (Pasture I was rested for two weeks in mid-). Pastures III and IV after cutting, were grazed continuously until fall the same as the rest, III by cattle and IV by sheep. Pasture I, after the two weeks rest period in [illegible], was cut for hay. It was then pastured again by cattle. In 1933 all the pastures were grazed continuously from the first week in May until fall, I, II, III and V by cattle and IV by sheep, geese and colts. No other treatments were given these pastures.

[illegible]

[illegible] grazing and fertilizer treatments, the effect of interspecific competition, the extent of winter injury, and the relative productivity of the various mixtures.

Botanical Analysis

To follow the changes in the botanical composition of the pasture sward, counts were made of plants of each species found in 12 systematically distributed strip-areas six feet long by two inches wide placed in each pasture (Fig. 1). Four similar strip-areas were also placed within each of three seventeen-feet-square fenced enclosures (Fig. 2) located in each pasture to serve as a check on those in the grazed area. To delimit the strip-area to be analysed a strong cord was stretched along both sides of it and drawn taut around the stakes shown in Figure 1. Plants occurring partly inside and partly outside of the cord were also included in the count. The unit of vegetation on which the counts were based was a discrete plant possessing an independent root system, as nearly as this could be determined without actually lifting the plants. Difficulty was encountered in the second and third years in distinguishing individual plants from new tillers in the case of the turf-forming species. In some cases, for this reason, it was found necessary to estimate rather than count the number of plants present. The results indicate that this procedure is sound. A similar modification of technique is reported by Hein and Vinall (22).

[illegible]

To [illegible] the changes in the botanical composition of the [illegible] stands, [illegible] were made of plants of each species found in [illegible] permanently [illegible] quadrats [illegible] feet long [illegible] (Fig. 1). [illegible] within each of these [illegible] (Fig. 2) located in each [illegible] in the grazed [illegible]. To [illegible] the [illegible] stretched a string [illegible] along [illegible] and drew [illegible] around [illegible] shown in Figure 1. Plants occurring partly inside and partly [illegible] were also included in the counts. The unit of [illegible] which the counts were based was a discrete plant possessing an independent root system, as nearly as this could be established without actually lifting the plants. [illegible] was encountered in the second and third years in distinguishing individual plants from [illegible] in the case of [illegible] plants. [illegible] for this [illegible] it was found necessary to estimate rather than count the number of plants present. The results indicate that [illegible] [illegible] is sound. A [illegible] of [illegible] is [illegible] by [illegible] and [illegible] (1951).

Fig. 1 - A test strip-area. The flat stakes shown are two inches wide and placed six feet apart, and mark off strip-areas in the pasture for periodic counting of plants.

Counts were made the first fall on all the pastures, except II. In pasture II the plants were too severely trampled by stock and too dry for positive identification. Three such counts were made in 1932, spring, summer and fall, respectively. In 1933 pressure of other work made it impossible to make more than two counts, one in the spring and one in the fall. It was hoped that the counts could be made at approximately the same time each year, but this proved to be out of the question owing to inclement weather and pressure of other work.

The check areas in the enclosures were intended to be analysed without disturbing the growth on them. This was found impracticable after the first count in the spring due to rankness of the growth. Consequently it was found necessary to cut these areas prior to the time when the counts were to be made. This was usually done when the yield cuts were made. The method of botanical analysis used is a modification of similar methods employed by Davies (5), at Aberystwyth, and Hein and Vinall (22) in Maryland.

The data were treated statistically and compiled into suitable tables expressing the botanical changes in the vegetation. The variability in the counts due to errors in sampling has been measured by computing probable error of

Counts were made the first half of all the seasons, except 19[illegible]. In seasons [illegible] the plants were too severely trampled by grazing and too dry for accurate identification. Three such counts were made in [illegible], spring, summer and fall, respectively. It would [illegible] of value every year if it [illegible] possible to make more than two counts, one in the spring and one in the fall. It was hoped that the counts could be made at approximately the same time each year, but this proved to be out of the question owing to [illegible] and [illegible] of [illegible] soil.

The forage grown in the enclosures were [illegible] to be analysed without disturbing the growth on them. This was found impracticable after the first count in the series due to [illegible] of the growth. Consequently it was found necessary to cut these areas prior to the time when the counts were to be made. This was usually done when the plant counts were made. The method of botanical analysis used is a modification of similar methods employed by Davies (5), et al, [illegible] and [illegible] in [illegible].

The data were treated [illegible] and [illegible] that [illegible] involving [illegible] botanical changes in the vegetation. The variability in the data due to error in sampling has been measured by computing probable error of

the mean, using Hayes' Deviation of the Mean Method (19) and Camp's formula, $P.E_{M} = 0.6745\sqrt{\frac{\Sigma(x - \bar{x})^2}{N(N - 1)}}$ (4).

Analysis of Productivity

Small areas six feet square within the enclosures (Fig. 2) were cut at intervals during the season to serve for the determination of the yield of the pasture. Two such cuttings were made in 1932 and three in 1933. The dates of cutting were a little irregular, due to inclement weather, lack of adequate transportation facilities and pressure of other work.

Yields per acre of air-dry matter were computed on the basis of two-pound composite sample lots, one drawn from the herbage cut from each enclosure. The samples were dried indoors to constant weight, some in wooden frames with cloth bottoms and some in wire-mesh baskets.

No attempt was made to compute probable errors on the yield results, as replication of the enclosures was insufficient to justify such treatment.

The percentages of leguminous and gramineous herbage present in the stands were determined by taking a one-pound composite sample from the herbage cut in each enclosure, and separating and weighing while still green, the two kinds of herbage and weeds, then determining their

[illegible]

Analysis of Herbage

Small areas six feet square within the enclosures (Fig. 3) were cut at intervals during the season to measure the [illegible] of the yield of the herbage. Two such cuttings were made in 1931 and three in 1932. The dates of cutting were a little irregular, due to inclement weather, lack of adequate [illegible], and other [illegible].

Yields and [illegible] of air-dry matter were computed on the basis of [illegible] composite samples, [illegible] drawn from the herbage cut from each enclosure. The samples were dried [illegible] to constant weight [illegible] and stored in [illegible] bottles.

No attempt was made to compute statistically the [illegible] results, as the [illegible] of the enclosures was insufficient to justify such treatment.

The percentages of legumes and graminaceous herbage present in the swards were determined by taking a ten-pound composite sample from the herbage cut in each enclosure, and separating and weighing while still green, the two kinds of herbage and weeds, then determining their

Fig. 2 - A test enclosure. The flat stakes shown are six feet apart and mark off strips for the periodic counting of plants. The central area is six feet square, and was cut for yield determinations.

percentages of the whole. Small air-tight metal cans were used to transport the samples from the field to the laboratory for analysis without loss in green weight. No attempt was made to separate and weigh the amount of each species present, on account of the difficulty of identifying small bits of vegetation and the tremendous amount of work entailed. The percentages of the more abundant species were, however, estimated. Estimations were made by spreading out each sample thinly on a long table and making a rough separation of various species. The percentage of each species was then approximated by eye. It was hoped that by this procedure some idea might be gained of the relative productivity of the more important species in the mixtures. These methods have been employed with good success by many European workers, notably Davies (5) and others.

Earliness and Periods of Active Growth

Seasonal growth of plants was studied by means of height measurements in the spring, again just before "turning in" the cattle in May, and before each cutting in the enclosures. It was thought that data procured in this way would show differences in earliness and rapidity of growth of the different species.

way would show differences in earliness and rapidity of growth of the different species.

General Notes

General notes were also taken both in the spring and in the fall on such items as general appearance and density of the pasture sward; palatability as indicated by evenness and closeness of grazing; the prevalence or absence of bare and trampled-out areas; the presence or absence of weeds; regenerative power, rapidity and earliness of growth, and apparent drought resistance and winterhardiness of the constituent species. These notes were supplemented by photographs taken to show the unevenness of grazing and vigor of growth of plants.

REVIEW OF METEOROLOGICAL DATA

Precipitation

A general impression of the precipitation month by month for the three years of the experiment may be had from the accompanying graph (Fig. 3) of the data in Table I. These data were collected by the Department of Field Crops on the Field Crops Farm, situated about two miles from the location of the pasture plots, and were taken from the department's records by the writer by kind permission.

Table I

Precipitation in inches at Edmonton* during 1931-1933

Year	Jan.**	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1931	0	0	1.25	0.44	1.93	6.60	3.53	4.47	0.70	0.97	0.75	0.95	21.59
1932	0.55	0.82	0.83	2.53	1.59	2.27	2.24	0.58	0.89	0.32	1.57	0.63	14.82
1933	0.45	0.74	1.93	0.66	2.05	3.32	3.03	1.30	2.07	1.69	0.98	2.85	21.07

* Measurements of precipitation were made on the Field Crops Farm, two miles from the location of the pasture plots.

** The snowfall data for the winter months were converted into rainfall data by dividing the former by 10.

Temperature

The temperature during the three years of the experiment was not unusually extreme, except in January, February and March of 1932 and 1933. The lowest Fahrenheit temperatures reached during these months in 1932 were -47°, -42° and -34°, and in 1933, -19°, -30° and -23°, respectively. The graphs (Figs. 4-6) illustrate the trends and extremes of the temperature data compiled in Table II. These data were also obtained from the records of the Department of Field Crops.

Table 5

Precipitation in inches at [illegible] 1961–1963

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1961	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1962	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1963	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

** [illegible]

Temperature

The temperature during the three years of the expedition was not unusually extreme, except in January, February and March of 1962 and 1963. The average [illegible] temperatures reached during these months in 1962 were [illegible], and in 1963, [illegible]. The graphs (Figs. 4-6) illustrate the annual and seasonal [illegible] of the temperature [illegible] in Table [illegible]. Figures were also obtained from the records of the [illegible].

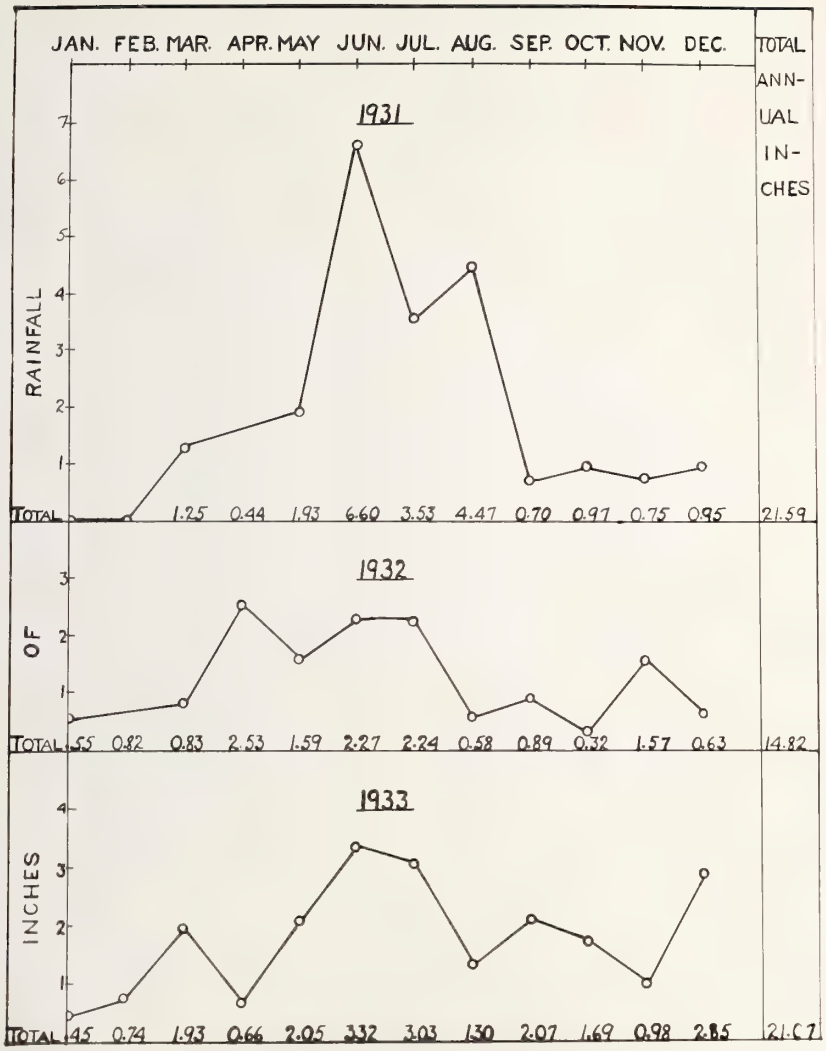

Fig. 3 - Precipitation in inches at Edmonton during 1931, 1932 and 1933.

Table II

Minimum monthly and average monthly temperatures (Fahrenheit) at Edmonton during 1931, 1932 and 1933

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1931												
Minimum	-9	+6	-30	+16	+27	+30	+40	+40	+28	+18	-18	-19
Date of occurrence	13	8	11	20	19	4	2	9	17	27	15	9
Average of the daily maximum temperature	31.2	40.2	28.6	56.1	63.7	68.1	72.8	70.8	60.0	54.6	32.0	23.8
Average of the daily minimum temperature	9.2	19.7	9.4	30.2	38.1	46.4	48.9	47.9	37.6	27.2	9.7	5.9
1932												
Minimum	-47	-42	-34	+24	+31	+34	+40	+29	+33	+5	-14	-23
Date of occurrence	31	1	7	2	15,25	17	12	31	13,22	28	14	8
Average of the daily maximum temperature	15.7	20.3	22.7	50.9	65.2	71.4	71.8	75.8	66.5	44.7	28.7	21.4
Average of the daily minimum temperature	4.2	6.4	1.2	33.3	40.9	48.2	49.4	49.2	39.9	24.9	11.0	4.1
1933												
Minimum	-19	-30	-23	+14	+31	+32	+39	+35	+26	+5	+3	-40
Date of occurrence	4	11	2	8	10	22	20	25	27	22	4	27
Average of the daily maximum temperature	14.1	17.6	29.6	47.2	62.1	69.5	72.7	75.5	59.1	45.7	38.3	-3.9
Average of the daily minimum temperature	5.0	4.7	6.4	27.6	39.1	45.0	47.7	47.8	37.4	23.8	23.0	-16.4

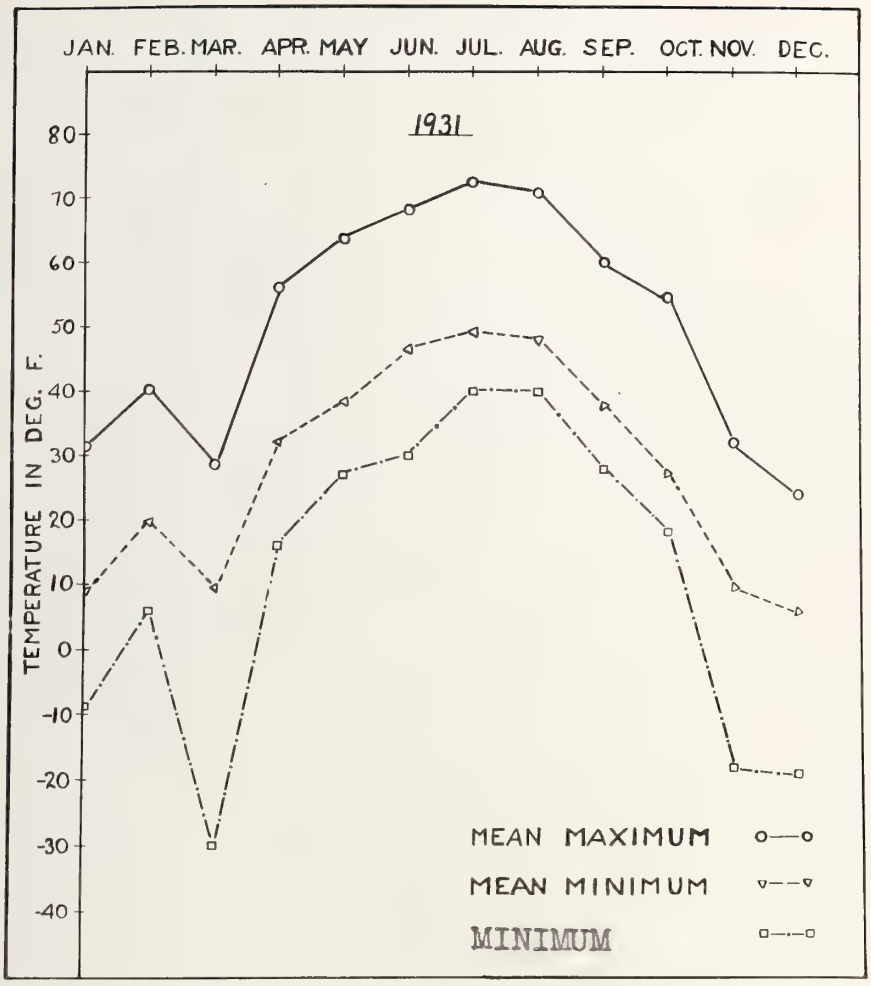

Fig. 4 - Minimum monthly and average monthly temperatures (Fahrenheit) at Edmonton in 1931.

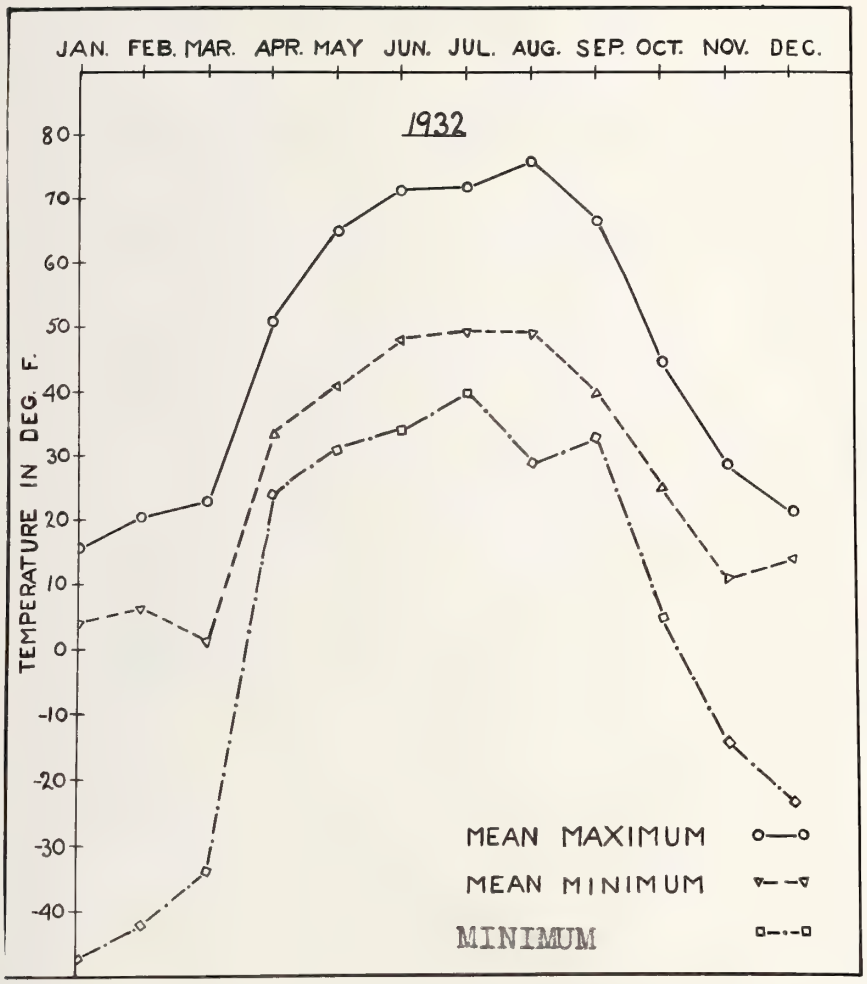

Fig. 5 - Minimum monthly and average monthly temperatures (Fahrenheit) at Edmonton in 1932.

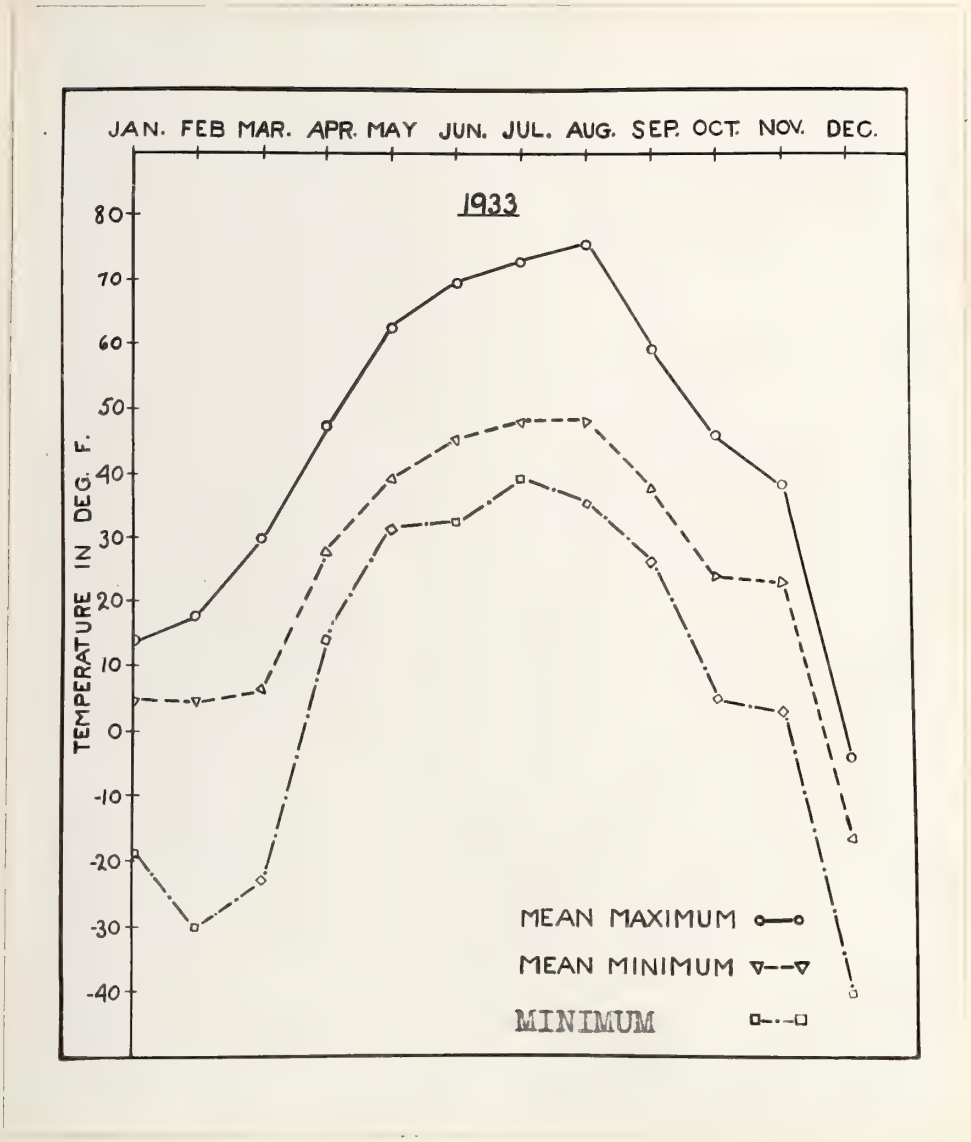

Fig. 6 - Minimum monthly and average monthly temperatures (Fahrenheit) at Edmonton in 1933.

EXPERIMENTAL RESULTS

Changes in Botanical Composition

The data obtained by frequency counts of plants of various species have been averaged and the respective probable errors computed. The results are given in Tables III to VIII. Table VIII contains data from Pasture VI for the fall of 1931 and the spring of 1932 only, as no further counts were made on this pasture because a part of it was destroyed by discing for the purpose of eradicating stinkweed and Canada Thistle.

For convenience of the reader the common and botanical names of the weeds given in Tables III-VIII are: Hemp nettle, Galeopsis sp.; Lambsquarter, Chenopodium album; Cinquefoil, Potentilla sp.; Knotweed, Polygonum sp.; Plantain, Plantago sp.; Stinkweed, Thlaspi arvense; Canada thistle, Circium arvense; Dandelion, Taraxacum officinale; Russian pigweed, Axyris amaranthoides.

Table III

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture I)

Species	1931	1932				1933			
	Autumn	Spring	Summer	Autumn		Spring		Autumn	
	Pasture	Pasture	pasture	Pasture	Check	Pasture	Check	Pasture	Check
Brome grass	5.17±0.68 12.71%	9.13±0.75 19.85%	9.25±0.99 17.23%	7.92±0.65 17.60%	14.75±0.48 29.21%	9.09±0.84 25.71%	13.83±0.71 33.94%	8.91±0.59 22.85%	12.67±0.64 30.90%
Crested wheat grass	4.59±0.48 11.29%	6.00±0.91 13.04%	4.25±0.49 7.92%	2.00±0.08 4.44%	3.67±0.40 7.27%	2.18±0.33 6.17%	2.50±0.27 6.14%	1.00±0.05 2.56%	1.67±0.06 4.07%
Western rye grass	3.75±0.61 9.22%	6.75±0.55 14.67%	5.92±0.69 11.03%	3.92±0.33 8.71%	3.75±0.50 7.43%	1.91±0.05 5.40%	2.92±0.31 7.17%	1.64±0.29 4.21%	1.50±0.07 3.66%
Alfalfa	10.42±0.62 25.62%	6.88±0.47 14.96%	9.00±0.55 16.77%	8.25±0.57 18.33%	8.33±0.34 16.50%	6.00±0.30 16.97%	7.00±0.37 17.18%	6.55±0.50 16.79%	7.75±0.38 18.90%
Sweet clover	5.75±0.29 14.14%	6.00±0.42 13.04%	5.33±0.56 9.93%	3.25±0.34 7.22%	1.00±0.31 1.98%	---	---	0.17*	---
Kentucky blue grass	4.67±0.48 11.48%	8.88±1.02 19.30%	9.67±0.74 18.02%	13.00±0.92 28.85%	11.33±1.03 22.44%	12.27±1.15 34.70%	11.92±0.48 29.25%	15.90±0.90 40.77%	13.85±0.64 33.78%
Alsike clover	6.25±0.57 15.37%	2.38±0.28 5.17%	10.25±0.81 19.10%	6.58±0.54 14.62%	7.67±0.76 15.19%	3.91±0.56 11.06%	2.58±0.47 6.33%	5.00±0.90 12.82%	3.58±0.70 8.73%
Total	40.67±1.64 100%	46.0 ±2.17 100%	53.67±2.22 100%	45.00±0.93 100%	50.50±1.50 100%	35.36±1.25 100%	40.75±1.02 100%	39.00±1.03 100%	41.00±0.67 100%
				Weeds					
Hemp nettle	0.25	---	0.33	---	---	---**	---**	---	---
Lambsquarter	0.25	---	0.17	---	---	---	---	---	0.08
Cinquefoil	--	0.08	0.17	0.18	0.33	---	0.25	0.17	0.33
Knotweed	--	---	---	---	---	---	---	0.08	---
Plantain	--	---	---	0.08	0.08	---	---	---	0.17
?	0.08	---	0.25	---	0.08	---	---	---	---
Total	0.58	0.08	0.92	0.26	0.49	---	0.25	0.25	0.58

* Not included in total as they were seedlings.

** Weeds too small for identification.

Dates of counts: 1931. November 3, 4.
1932. April 30, June 6,7, August 20 (pasture and check).
1933. May 13 (pasture), 24 (check), August 26 (pasture and check).

Table IV

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture II)

Species	1931	1932				1933			
	Autumn	Spring	Summer	Autumn		Spring		Autumn	
	Pasture	Pasture	Pasture	Pasture	Check	Pasture	Check	Pasture	Check
Western rye grass	*---	5.50±0.76 9.13%	7.18±0.50 13.23%	4.33±0.46 11.27%	8.50±0.76 15.74%	3.50±0.41 12.21%	6.50±0.59 19.40%	1.92±0.29 7.09%	5.00±0.55 14.89%
Altaswede red clover	---	11.25±0.72 18.67%	10.27±0.58 18.92%	8.33±0.66 21.68%	9.00±0.63 16.67%	5.17±0.64 18.03%	5.42±0.39 16.18%	4.75±0.59 17.54%	4.83±0.43 14.38%
Timothy	---	28.13±1.44 46.68%	22.73±0.99 41.88%	16.25±0.65 42.28%	22.58±0.72 41.81%	16.00±0.48 55.81%	14.92±0.70 44.54%	15.50±0.47 57.24%	16.67±0.69 49.64%
Alsike clover	---	15.38±1.07 25.53%	14.09±1.11 25.96%	9.50±0.61 24.72%	13.92±0.75 25.78%	4.00±0.66 13.95%	6.67±0.59 19.94%	4.92±0.55 18.17%	7.08±0.69 21.08%
Total	---	60.25±2.05 100%	54.27±1.95 100%	38.43±1.45 100%	54.00±1.18 100%	28.67±1.14 100%	33.50±1.10 100%	27.08±1.16 100%	33.58±1.11 100%
				Weeds					
Kentucky blue grass **	---	---	0.55	0.42	0.08	1.42	0.33	1.75	1.08
Brome grass **	---	---	--	--	--	--	0.33	--	--
Canada thistle	---	---	--	--	0.18	--	--	--	--
Plantain	---	---	--	--	0.25	--	0.25	--	0.17
Shepherd's purse	---	---	--	0.08	0.08	--	--	--	0.17
Dandelion	---	---	--	0.08	--	--	--	--	--
Cinquefoil	---	---	--	--	--	0.08	--	0.08	--
Knotweed	---	---	--	--	--	--	--	--	0.17
Russian pigweed	---	---	--	--	--	--	--	0.17	--
Total	---	---	--	0.16	0.51	0.08	0.25	0.25	0.51

* Identification made impossible by too much trampling.
** Not seeded. Not included in the weed totals.

Dates of counts: 1931. October 26.
1932. April 30, June 4, August 13 (pasture and check).
1933. May 14 (pasture), 24 (check) August 28 (pasture and check).

Table V

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture III)

Species	1931	1932				1933			
	Autumn	Spring	Summer	Autumn		Spring		Autumn	
	Pasture	Pasture	Pasture	Pasture	Check*	Pasture	Check	Pasture	Check
Alfalfa	4.83±0.72 9.69%	8.75±0.82 13.92%	7.67±0.62 13.24%	6.92±0.49 14.34%	--	5.33±0.63 13.87%	--	4.33±0.39 11.57%	--
Brome grass	8.00±1.09 16.05%	9.87±1.83 15.70%	9.08±1.10 15.68%	10.67±0.79 22.11%	--	11.20±1.09 29.15%	--	10.08±0.75 26.94%	--
Kentucky blue grass	20.92±1.02 41.98%	28.63±1.29 45.53%	25.08±1.50 43.30%	22.25±1.18 46.11%	--	20.83±1.13 54.22%	--	21.92±0.56 58.58%	--
Dutch clover	16.08±0.80 32.27%	15.63±1.15 24.86%	16.08±0.74 27.76%	8.42±0.44 17.45%	--	1.08±0.32 2.81%	--	1.08±0.32 2.88%	--
Total	49.83±1.50 100%	62.88±2.56 100%	57.92±1.56 100%	48.25±1.33 100%	--	38.42±1.27 100%	--	37.42±0.83 100%	--
				Weeds					
Stinkweed	2.00	**	0.50	---	--	1.00	--	---	--
Plantain	0.33	---	0.25	0.25	--	--	--	0.17	--
Cinquefoil	0.83	---	0.33	0.83	--	0.33	--	0.17	--
Dandelion	0.08	---	--	0.08	--	0.08	--	0.08	--
?***	0.25	---	--	---	--	--	--	---	--
Total	3.49	---	1.08	1.16	--	1.41	--	0.42	--

* No enclosures were placed in this pasture.
** Weeds were too young for identification.
*** Identification uncertain.

Dates of counts: 1931. October 26.
1932. April 30, June 9, August 18.
1933. May 14, September 2.

Table VI

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture IV)

Species	1931	1932				1933			
	Autumn	Spring	Summer	Autumn		Spring		Autumn	
	Pasture	Pasture	Pasture	Pasture	Check	Pasture	Check	Pasture	Check
Crested wheat grass	6.83±0.82 13.73%	2.63±0.40 5.16%	4.33±0.50 7.08%	4.08±0.51 7.63%	5.00±0.49 8.50%	3.25±0.35 8.55%	3.00±0.38 8.22%	1.75±0.32 4.65%	1.50±0.07 3.67%
Brome grass	4.08±0.61 8.20%	6.75±1.02 13.24%	6.92±1.01 11.31%	8.83±0.94 16.50%	11.25±0.62 19.12%	8.25±0.80 21.71%	11.50±0.63 31.51%	9.42±0.74 25.00%	13.00±0.90 31.84%
Kentucky blue grass	18.25±1.47 36.68%	20.13±0.98 39.47%	25.08±1.83 41.00%	25.50±1.30 47.66%	25.08±1.75 42.63%	25.58±0.90 67.32%	20.33±0.89 55.70%	22.83±0.63 60.61%	21.75±1.08 53.27%
Dutch clover	11.75±0.72 23.62%	15.12±1.08 29.65%	20.25±0.70 33.10%	11.92±0.78 22.28%	15.08±0.58 25.63%	0.92±0.29 2.42%	1.67±0.28 4.58%	3.67±0.49 9.74%	3.58±0.88 8.77%
Sweet clover	8.83±0.58 17.75%	6.37±0.69 12.49%	4.58±0.38 7.49%	3.17±0.39 5.93%	2.42±0.34 4.11%	--	--	--	1.00±0.33* 2.45%
Total	49.75±1.99 100%	51.00±2.48 100%	61.17±2.82 100%	53.50±2.07 100%	58.83±1.50 100%	38.00±1.28 100%	36.50±0.87 100%	37.67±0.91 100%	40.83±1.23 100%
				Weeds					
Western rye grass**	---	--	0.08**	--	--	--	--	--	--
Stinkweed	0.33	--	0.25	--	--	--	--	--	--
Knotweed	---	--	--	0.08	--	--	--	0.08	--
Cinquefoil	0.08	--	0.25	0.08	0.08	0.08	--	0.08	--
Lambsquarters	---	--	--	--	--	0.08	--	0.08	--
Plantain	---	--	0.16	0.18	--	--	--	--	--
Dandelion	0.25	--	--	0.25	--	0.17	0.08	0.25	0.25
Total	0.66	--	0.66	0.59	0.08	0.33	0.08	0.49	0.25

*Sweet clover seedlings. A few Dutch seedlings showing up.
**Not seeded.

Dates of counts: 1931. October 27, 29.
1932. April 20, June 11, August 24 (pasture), 23 (check).
1933. May 19, 20 (pasture), 27 (check), August 28 (pasture), 26 (check).

Table VII

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture V)

Species	1931	1932				1933			
	Autumn	Spring	Summer	Autumn		Spring		Autumn	
	Pasture	Pasture	Pasture	Pasture	Check	Pasture	Check	Pasture	Check
Crested wheat grass	5.25±0.54 13.40%	4.37±0.49 10.53%	5.17±0.56 10.29%	3.92±0.34 10.34%	5.75±0.58 13.19%	3.64±0.32 10.82%	6.33±0.47 19.23%	3.08±0.26 10.07%	6.08±0.65 18.06%
Kentucky blue grass	13.25±1.46 33.83%	19.12±2.15 46.07%	25.42±1.81 50.58%	20.75±0.99 54.72%	23.90±1.25 54.84%	25.50±1.83* 75.83%	21.00±0.74 63.79%	22.75±0.67 74.40%	21.92±0.59 65.10%
Alfalfa	6.75±0.49 17.23%	4.88±0.37 11.76%	5.58±0.48 11.10%	4.42±0.43 11.66%	5.67±0.39 13.01%	4.00±0.28 11.89%	5.26±0.44 15.98%	3.75±0.57 12.26%	5.00±0.42 14.85%
Dutch clover	13.92±0.75 35.54%	13.13±0.85 31.64%	14.08±0.60 28.02%	8.83±0.42 23.29%	8.25±0.69 18.93%	0.50±0.05 1.49%	0.33±0.05 1.00%	1.00±0.36 3.27%	0.67±0.28 1.99%
Total	39.17±1.90 100%	41.50±2.61 100%	50.25±1.84 100%	37.92±0.90 100%	43.58±1.59 100%	33.63±1.75 100%	32.92±0.88 100%	30.58±0.86 100%	33.67±0.70 100%
				Weeds					
Brome **	--	--	--	--	--	--	--	--	0.17
Stinkweed	--	--	0.33	--	--	--	0.25	--	--
Russian pigweed	--	--	--	--	--	--	--	--	0.08
Shepherd's purse	0.17	--	--	--	--	--	--	0.17	0.08
Dandelion	--	--	--	--	--	--	--	--	0.08
Lambsquarter	--	--	--	--	--	--	--	0.08	--
Cinquefoil	0.17	--	0.25	0.25	0.08	0.27	0.08	--	--
?***	0.17	--	--	--	--	--	--	--	--
Knotweed	--	--	--	0.33	--	--	--	--	--
Plantain	--	--	--	0.33	--	--	--	0.17	--
Total	0.51	--	0.58	0.91	0.08	0.27	0.33	0.42	0.24

* The frequencies were very uniform, except in the last strip area.
** Not seeded.
*** Not identified.
Dates of counts: 1931. November 4.
1932. April 29, May 28, August 14(pasture and check).
1933. May 14 (pasture), 24 (check), August 29 (pasture and check).

Table VIII

Frequency of plants of various species per square foot as determined by counts of the numbers of plants in 12 systematically distributed sample strips

(Pasture VI)

Species	1931 Autumn Pasture		1932 Spring Pasture	
Brome	8.17 ± 0.60	36.72%	9.40 ± 0.74	43.32%
Alfalfa	14.08 ± 1.06	63.28%	12.30 ± 0.72	56.68%
Total	22.25 ± 1.04	100%	21.70 ± 1.04	100%
	Weeds			
Stinkweed	1.08		*	
Dandelion	0.08			
Cinquefoil	1.08			
Plantain	0.08			
Lambsquarter	0.08			
Total	2.40			

* Weeds were not counted in this pasture in 1932 as they were too small for identification.

Dates of counts: 1931. November 4.
1932. April 29.

Yields of Green Matter and Dry Hay, Also Proportions of Legumes, Grasses and Weeds in the Cut Herbage

The yields secured from pastures I, II, IV and V were computed in terms of tons per acre of green herbage and dry hay. The results are presented in the first four columns of Tables IX to XII. The figures in the last three columns

of the same tables give the percentages (green weight basis) of leguminous and gramineous herbage and weeds, as determined from analysis of composite one-pound samples from the cut material.

Table IX

Yields per acre of green matter and dry hay, also percentages of legumes, grasses and weeds in the cut herbage

(Pasture I)

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 11	27,003	8,150	45.81	54.12	-
	Aug. 30	4,623	1,807	35.19	64.88	-
				Average	Average	
	Total	31,626	9,957	40.50	59.50	-
1933	June 5	8,161	2,463	21.88	78.12	Trace
	July 13	8,067	2,001	51.56	48.44	Trace
	Aug. 19	5,615	1,586	79.69	20.31	Trace
				Average	Average	
	Total	21,843	6,050	51.06	48.94	Trace

Table X

Yields per acre of green matter and dry hay, also percentages of legumes, grasses and weeds in the cut herbage

(Pasture II)

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 5	20,229	6,005	36.50	63.50	Trace
	Aug. 27	4,740	1,975	29.56	70.44	Trace
				Average	Average	
	Total	24,969	7,980	33.03	66.97	Trace
1933	June 6	9,195	2,501	4.13	95.87	Trace
	July 15	6,248	2,068	31.25	68.75	Trace
	Sept. 1	2,354	841	22.13	77.87	Trace
				Average	Average	
	Total	17,797	5,410	19.17	80.83	Trace

Table XI

Yields per acre of green matter and dry hay, also percentages of legumes, grasses and weeds in the cut herbage

(Pasture IV)

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 7	27,548	7,467	48.81	51.19	-
	Aug. 29	6,536	2,706	31.81	68.19	-
				Average	Average	
	Total	34,084	10,173	40.31	59.69	-
1933	June 6	7,536	2,296	Trace	97.80	2.20
	July 14	3,866	1,287	3.13	94.38	2.49
	Aug. 30	1,372	522	1.06	98.16	0.78
				Average	Average	Average
	Total	12,774	4,105	1.40	96.78	1.82

Table XII

Yields per acre of green matter and dry hay, also percentages of legumes, grasses and weeds in the cut herbage

(Pasture V)

Year	Cutting dates	Green weight in pounds per acre	Dry weight in pounds per acre	Percentages		
				Legumes	Grasses	Weeds
1932	July 9	24,172	7,617	41.44	54.81	3.74
	Aug. 31	4,958	2,036	53.63	46.38	Trace
				Average	Average	Average
	Total	29,130	9,653	47.54	50.59	1.87
1933	June 9	10,676	3,283	32.50	67.50	-
	July 16	7,894	2,640	57.06	42.94	-
	Sept. 4	4,260	1,452	65.88	34.12	-
				Average	Average	
	Total	22,830	7,375	51.81	48.19	-

Seasonal Productivity as Shown by Earliness and Periods of Active Growth of the Constituent Species

Tables XIII to XVII contain height data collected at various intervals during the growing season. Figure 7 illustrates the botanical composition and relative heights of the herbage for the pastures in the middle of July, 1932. Figures 2, 8 and 9 show the botanical composition and heights of plants in the three enclosures in Pasture V in the middle of June, 1933.

Table XIII

Average heights in inches of plants of various species

(Pasture I)

Species	1932			1933		
	Summer*		Autumn	Spring	Summer	Autumn
	Pasture	Enclosure	Enclosure	Enclosure	Enclosure	Enclosure
Brome grass	18.0	54.8	19.0	20.5	21.4	11.1
Crested wheat grass	15.0	41.3	15.6	14.9	19.6	6.8
Western rye grass	14.3	48.6	13.8	14.7	19.0	10.0
Alfalfa	12.4	35.2	16.0	13.5	18.3	16.3
Sweet clover	12.0	51.7	19.0	--	--	--
Kentucky blue grass	12.5	36.3	11.7	12.7	16.3	8.9
Alsike clover	8.6	34.2	5.6	8.5	14.9	5.8

* Circumstances did not permit making height measurements for this pasture in the spring of 1932.

Dates of measurements: 1932. May 26, July 11, August 30.
1933. June 5, July 13, August 29.

Table XIV

Average heights in inches of plants of various species

(Pasture II)

Species	1932				1933		
	Spring	Summer		Autumn	Spring	Summer	Autumn
	Pasture	Pasture	Enclosure	Enclosure	Enclosure	Enclosure	Enclosure
Western rye grass	3.9	15.3	42.5	17.6	13.7	18.3	7.9
Altaswede red clover	1.8	8.7	22.9	8.3	7.6	13.4	6.1
Timothy	4.8	16.0	40.6	21.3	16.4	19.5	7.5
Alsike clover	2.2	10.3	25.9	9.3	7.9	13.4	5.6

Dates of measurements: 1932. May 5, June 4, July 5, August 27.
1933. June 6, July 15, September 1.

Table XV

Average heights in inches of plants of various species

(Pasture III)

Species	1932			1933
	Spring	Summer		Spring
	Pasture*	Pasture	Pasture	Pasture
Alfalfa	3.3	15.5	28.1	3.0**
Brome grass	6.6	26.1	48.1	4.0
Kentucky blue grass	4.2	20.1	31.4	3.0
Dutch clover	2.2	10.0	20.8	-

* No enclosures were placed in this pasture.
** These heights were estimated by eye.

Dates of measurements: 1932. May 5, June 9, July 2.
1933. May 6.

Table XVI

Average heights in inches of plants of various species

(Pasture IV)

Species	1932					1933			
	Spring	Summer			Autumn	Spring	Summer		Autumn
	Pasture	Pasture	Pasture	Enclosure	Enclosure	Pasture	Enclosure	Enclosure	Enclosure
Crested wheat grass	7.3	19.3	32.0	37.3	16.3	3.5*	15.0	14.7	6.9
Brome grass	7.5	26.4	47.3	50.0	18.3	4.0	18.2	15.6	7.8
Kentucky blue grass	3.9	23.8	32.3	36.4	12.7	2.0	12.3	9.7	5.8
Dutch clover	2.4	11.7	18.5	21.8	7.5	1.0	5.3	5.7	2.6
Sweet clover	2.3	18.3	35.0	45.3	19.9	-	-	-	-

* Estimated by eye.

Dates of measurements: 1932. May 5, June 11, July 2, July 7, August 29.
1933. May 6, June 9, July 14, August 30.

Table XVII

Average heights in inches of plants of various species

(Pasture V)

Species	1932			1933			
	Summer*		Autumn	Spring		Summer	Autumn
	Pasture	Enclosure	Enclosure	Pasture**	Enclosure	Enclosure	Enclosure
Crested wheat grass	13.8	36.5	21.7	3.0	20.5	19.1	8.5
Kentucky blue grass	8.5	33.1	12.1	3.0	16.5	15.0	7.4
Alfalfa	7.5	28.4	19.1	2.0	14.4	18.6	11.1
Dutch clover	4.6	19.6	6.4	1.0	5.9	--	--

* Circumstances did not permit making height measurements for this pasture in the spring of 1932.

** Estimated heights.

Dates of measurements: 1932. May 25, July 9, August 3.
1933. May 6, June 9, July 18, September 4.

Fig. 7 - The sheaves shown represent composite samples drawn from the cut herbage of each of the five pastures when the first cutting was taken in 1932. They serve to illustrate in a general way the botanical composition of each pasture mixture, and the relative heights of constituent plants at the time of cutting.

The dates of cutting and heights in inches of sheaves are as follows:

Pasture	Date of cutting	Maximum height in inches
I	July 13	48
II	" 16	46
III*	" 13	53
IV	" 16	52
V	" 16	36

* This sample was drawn from the mown hay in Pasture III.

Fig. 8 - A photograph showing the botanical composition and average height (20 in.) of the stand within one of the enclosures (north-west) in Pasture V at the time of the first cutting in 1933. The photograph was taken June 17.

Fig. 9 - A photograph showing the botanical composition and average height (20 in.) of the stand within one of the enclosures (south-west) in Pasture V at the time of the first cutting in 1933. The photograph was taken June 17.

Palatability of Various Species as Indicated by the Selectivity of the Grazing Animals

The data secured on the relative palatability of the constituent species are in the form of critical notes taken at intervals throughout the period of the experiment. These notes have been supplemented with photographs (Figures 10 and 11) of one pasture illustrating typical selectivity of the grazing animals.

DISCUSSION

Weather Conditions

Weather conditions were particularly favorable at the time of seeding and through the first summer, also the following spring and early summer, but thereafter rainfall was exceptionally deficient. The drought periods occurring each year in the latter part of the summer interfered with normal seasonal growth. This retardation in growth in 1932 and 1933 in August and September is reflected more particularly in the growth of timothy, Kentucky blue grass, western rye grass, crested wheat grass

[illegible]

[illegible]

These tests have been subjected [illegible]

[illegible] of the [illegible]

[illegible]

Weather conditions.

[illegible]

At the time of seeding [illegible] the following points are clearly evident, but the rainfall [illegible] occurring each year in the latter part of the summer interfered with normal growth. [illegible] in growth in 1933 and 1935 in August and September is reflected more particularly in the growth of [illegible] Kentucky blue grass, western rye grass, crested wheat grass

Fig. 10 - A photograph illustrating the selectivity of cattle in grazing. The grass which appears ungrazed is crested wheat grass. The photograph was taken at random in Pasture V on October 11, 1933.

Fig. 11 - This photograph illustrates the close grazing of Kentucky blue grass and alfalfa, and the avoidance of crested wheat grass. The stakes shown are approximately 4 in. above the ground level. The photograph was taken of one of the strip-areas in Pasture V on October 11, 1933.

and the three clovers, Dutch, Alsike and Altaswede red clover. Alfalfa and sweet clover were not markedly affected by drought during these months. The growth of brome was only slightly reduced. This reduced rate of growth of blue grass, timothy and other grasses in late summer is also reported by Vinall and Hein (38), who believe that it is partly due to an apparent physiological response of the plant to its environment and not to drought alone, i.e., there are periods during the season when certain plants are semi-dormant, and these periods are coincident with that time of year when these plants normally produce seed. The height data, with reference to timothy, western rye and Kentucky blue grasses in particular, appear to support this view. It is also probable that the marked decrease in the percentage of grasses in the cut herbage (Tables IX-XII) in late summer was at least partly due to this decreased growth rate of grasses referred to by Vinall and Hein.

Winter temperature and snow covering are also two factors involved in the survival of a pasture stand. The extremely low temperatures which occurred in January, February and March of 1932 and during the same months of 1933 are undoubtedly a factor in the almost complete killing out of Dutch clover, and in the marked decreases in alfalfa, Altaswede red clover and Alsike clover during these two years.

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clover. Alfalfa and [illegible]

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brome was only slightly [illegible]

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1953 are undoubtedly a factor in the almost complete [illegible]

out of Dutch clover, and in the marked decrease in alfalfa,

alsike, red clover and [illegible]

years.

Experimental Results

Changes in Botanical Composition.

The results of plant counts supplemented by critical notes indicate quite definitely in a general way the limitations and good qualities of the six pasture mixtures studied. Since the quality of a pasture mixture is no better than the combined qualities of its constituent species, it would seem appropriate to discuss these species individually before making more general and critical comments on the mixtures as such.

From a critical perusal of Tables III to VIII it will be readily seen that the more important species from the standpoint of maintaining a pasture stand in status quo are brome grass, Kentucky blue grass and alfalfa. All the other species present, according to the data, are in a state of decline after the expiration of the second season, with complete killing out of Dutch clover and sweet clover. Sweet clover being biennial would be expected to disappear at the end of the second year of growth, but this is not true of Dutch clover, which is a perennial plant. Its killing out must be accounted for in some other way.

The killing out of Dutch clover in 1932 and 1933 was probably due to four main factors: Firstly, interspecific competition; secondly, nature of the plant itself;

[illegible]

[illegible]

The results of [illegible]

units indicate [illegible]

types and seed [illegible]

among the plants, [illegible]

seedlings [illegible]

appropriate [illegible]

making them [illegible]

as well.

From a [illegible]

will [illegible] readily [illegible]

the standpoint of maintaining a [illegible] stand [illegible]

are grown [illegible]

other species present, [illegible]

able to [illegible] after [illegible]

with [illegible] falling out of [illegible]

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less of [illegible] clover, which is a perennial plant. This

falling out must be accounted for in some other way.

The falling out of [illegible]

was probably due to four main reasons: firstly, inter-

specific competition; secondly, [illegible]

thirdly, droughty conditions the previous fall (1932); and, fourthly, extremely low temperatures during the winter months combined with an inadequate snow covering. The data (Tables V, VI and VII) show that the decline of this species began in the late summer of 1932 and continued with almost complete killing out in the spring of 1933. This decrease was about equal in Pastures III, IV and V which contained Dutch clover in the mixture. Pasture III had produced very rank growths of brome grass and alfalfa, Pasture IV of brome and sweet clover and Pasture V of crested wheat grass and alfalfa in 1932 (Fig. 3, and Tables XIII, XV, XVI and XVII). Pastures III and Iv, it will be recalled, were not grazed in June 1932, but were cut for hay in the second week in July. Moreover, these two pastures were grazed very closely until fall after the hay crop had been removed, one (IV) by sheep and the other (III) by young bulls. Accordingly, the writer is led to suspect that the combined effects of shading and crowding of the tall growing species followed by severe grazing the second season contributed to the killing of Dutch clover. Also drought and hot weather (Tables I and II) in August and September of 1932 combined with the crowding and shading effects of brome, Kentucky blue and other grasses, and sweet clover and alfalfa may have so weakened the Dutch clover plant that it could no longer withstand the rigorous climate of the winter which

[illegible]

[illegible] (Tables V, VI and VII) [illegible]

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III and IV, it will be remembered, [illegible]

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[illegible] (Tables I and III) [illegible]

with the crowding and [illegible]

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[illegible]

followed. However, no definite proof can be given to support the view that winter temperature was the final cause of killing of this plant. Furthermore, the results (Tables V, VI and VII) seem to suggest that Dutch clover might only be a relatively short-lived perennial. This view finds support in the work of Roberts and Jones (30) and Fenton (13), who found Dutch clover of value in pasture mixtures only in the first year of grazing, as in subsequent years it rapidly disappeared. Accordingly, from the results obtained and the supporting evidence in the literature at hand, the writer came to the conclusion that Dutch clover as a constituent of pasture mixtures is very short-lived and of little value over a period of more than two years.

Two other species which also proved to be very undesirable both from the point of view of persistence (Tables III, IV, VI, VII) and of palatability (Figures 10 and 11), which will be discussed later, are crested wheat and western rye grasses. The former, according to the data, is apparently the less desirable grass of the two. Both of these species had gone out almost entirely in pastures I, II and IV by the autumn of 1933; crested wheat grass seemed to have decreased less in Pasture V, however, for some unaccountable reason. No work with these grasses is reported in the literature reviewed.

A very noticeable feature of Pasture II was the reduction of Alsike and Altaswede clovers by about 60 percent by the end of the third season. Alsike by the end of 1932 was found localized in low lying areas in Pastures I and II where, owing to greater moisture, this plant does better than Altaswede red clover. The decline of Alsike is also reported by European workers, notably Fenton (12) and Stapledon and Davies (34) and by Hein and Vinall (22), working in the United States. It was only in districts where moisture was more abundant that this plant competed successfully in mixtures with red clover. For these reasons the undesirablity of Alsike in pasture mixtures, except on low land, will be readily seen. Nor is Altaswede red clover altogether satisfactory for permanent pasture purposes because of its susceptibility to winter injury and its short life habit, as brought out in the data. This view finds support also in Fenton's work (13).

Timothy gave evidence of being more persistent than western rye grass, as it had only decreased 20 percent by the end of 1933. Fenton (12) reports that timothy was not a success in pasture mixtures in England, it being crowded out and its place taken by Lolium and Agrostis species, and by Dactylis glomerata. This condition would not be met with here, owing to our semi-arid climate under which these latter species would be less competitive.

The persistence of alfalfa (alfalfa had decreased slightly), brome and Kentucky blue grass is clearly brought out in the data. The item of importance in this connection is the fact that they appear to form an association without causing any injury one to the other. Kentucky blue grass, while less desirable from a standpoint of yield, as will be shown later, is an excellent turf-forming species, which appears to render it a potent enemy against weeds. This is amply supported in the literature. Brome was also shown to be aggressive and to hold weeds well in check.

The counts of weeds reveal no significant changes. The number of counts made need to be greatly increased before definite changes could be fully established. Critical notes reveal, however, that weeds are kept well in check by the turf-forming grass species, i.e., brome and Kentucky blue grasses.

Productivity of Pastures.

Yields of green matter and dry hay. The yields secured from each pasture in both harvest years were very gratifying, except those from Pasture IV in 1933. The total yields of dry hay the first harvest year were, on the average, a third greater than those in the second year. This might be expected, especially Pastures I and IV, in view of the crowding out of Dutch clover on the one hand and the complete elimination of the bulky sweet clover on the other.

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The number of [illegible]

[illegible]

[illegible], however, that [illegible] are kept well in check by the

turf-forming grass species, i.e., [illegible] and Kentucky blue

grasses.

Productivity of [illegible]:

Yields of [illegible]. The [illegible]

[illegible] from each pasture in both harvest years were [illegible]

[illegible], except those from Pasture IV in [illegible]. The

total yields of dry hay the first harvest year were, on the

average, a third greater than those in the second year. This

[illegible], especially Pastures I and II, in view of

the crowding out of Dutch clover on the one [illegible]

complete elimination of the bulky sweet clover [illegible]

The decrease in yields from the first to the second year was less marked in Pastures II and V, the reason being that the former pasture contained clovers which had decreased but little and that the latter contained alfalfa which yielded even more abundantly in the second year. The pastures arrange themselves in the following order as regards maximum yields: 1932, IV, I, V and II; 1933, V, I, II and IV. It will be observed that Pasture IV changed from top place in 1932 to bottom place in 1933 in yielding capacity. This is a particularly interesting result when compared with the yields from Pasture I in 1933, which also contained sweet clover. The increment of yield in this pasture must be attributed mainly to alfalfa. It will also be noted that Pasture V, which fell in third place in 1932, rose to first place in 1933. This change may be accounted for on the basis of more rapid growth of alfalfa and Kentucky blue grass. Moreover, it will also be seen that the position of Pasture I remains unchanged in the order of yield from the first to the second harvest year in spite of the dying out of sweet clover. This is also attributable largely to increased growth of alfalfa and partly to Kentucky blue and brome grasses. Pasture II changed from bottom to third place from 1932 to 1933. This may be accounted for mainly by the very excellent growth made by the timothy even in the drier months, the clovers added little to the bulk of the hay at that time of the season.

the [illegible]

and [illegible]

the [illegible]

[illegible] and [illegible]

yielded even [illegible]

[illegible]

[illegible]

4, 11 and 17. It will be [illegible]

from [illegible] place in [illegible]

generally. This is a particularly [illegible]

[illegible] with the [illegible]

[illegible] cases. The [illegible]

[illegible]

be noted that [illegible]

place to first [illegible]

fly on the basis of more than [illegible]

[illegible] blue grass. Moreover, it will [illegible]

the [illegible]

[illegible] from the first to the second [illegible]

the [illegible] out of first place. This is [illegible]

[illegible] to [illegible]

[illegible] and [illegible]

[illegible] to third place from [illegible]. This [illegible]

accounted for mainly by the very excellent growth [illegible]

the timothy even in the [illegible]

little to the bulk of the [illegible]

Pasture V maintained the greatest uniformity of yield from cutting to cutting and from the first to the second harvest year. The decrease in its yield from 1932 to 1933 was only 25 percent, on the average, as against 40 in I, 56 in II and 60 percent in IV. This indicates quite definitely that Pasture V, from the standpoint of productivity alone, is more desirable than any of the other three. Pasture IV, on the other hand, is shown to be the most disappointing mixture in the whole experiment; for this reason it would seem that it should be discriminated against when compounding seed mixtures for pasture in the Edmonton district.

The proportion of the cut herbage available as pasturage is given by Wolfe (39) as from 40 to 65 percent of the yield of hay. Other investigators simply total the results from the various cuts to arrive at pasture yield (12, 31).

The effect of the frequency of cutting on the yield of pastures should not be overlooked. The results indicate that yield is a decreasing function of the frequency of cutting, which is in agreement with Shutt (31), Fagan (9), Aldous (1), Fenton (12), and other investigators.

Seasonal productivity as indicated by changes in the proportions of legumes, grasses and weeds. Certain seasonal changes have occurred in the percentages of legumes and grasses in the pasture herbage. This is well illustrated in Tables IX to XIII (last three columns). These changes in

Mixture I [illegible] the [illegible] of [illegible]

cutting or [illegible] [illegible] [illegible] [illegible] [illegible]

that. The decrease in [illegible] [illegible] [illegible] [illegible]

Mixture I, [illegible], [illegible] [illegible] [illegible] [illegible]

of [illegible] [illegible]. [illegible] [illegible] [illegible]

Mixture V, from the [illegible] [illegible] [illegible]

more desirable [illegible] [illegible] [illegible] [illegible]

the upper [illegible], as [illegible] [illegible] [illegible]

in the above experiment [illegible] [illegible] [illegible]

it should be discontinued [illegible] [illegible] [illegible]

[illegible] the [illegible] [illegible] the [illegible] [illegible].

The [illegible] of [illegible] [illegible] [illegible] of [illegible] is given in Table [illegible], [illegible] [illegible] the yield of [illegible]. [illegible] investigators [illegible] [illegible] results from the [illegible] [illegible] [illegible] [illegible] (15, 45).

The effect of the frequency of cutting on the yield of [illegible] should not be overlooked. The [illegible] [illegible] that yield is a decreasing function of the frequency of cutting which is in agreement with [illegible], [illegible], [illegible], Parker (13), and other investigators.

Seasonal [illegible] in [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible].

Seasonal changes have occurred in the [illegible] of [illegible] and grasses in the mixture herbage. This is [illegible] in Tables IX to XIII [illegible] [illegible]. [illegible] [illegible]

the proportions of legumes and grasses may be attributed mainly to four factors, namely, climate, plant competition, periodic defoliations and the nature of the plants themselves.

In the discussion of yield the importance of highly productive and persistent leguminous species was shown. It was seen that alfalfa was a species of this type. The results of the botanical analysis by weight bring this out even more forcibly. This is especially true of the 1933 results. The estimations of the percentages of the constituent species reveal very striking changes.

The leguminous content of the herbage in the first cutting in 1932 was only slightly below the percentage of grasses, and was composed chiefly of sweet clover in Pastures I and IV, alfalfa in Pasture V, and of about equal quantities of red and Alsike clovers in Pasture II. The second cutting in the same year revealed an increase in grasses with a corresponding decrease in the leguminous content. This time alfalfa predominated in Pasture I, and sweet clover in IV in the latter respect, Dutch clover was present only in small quantities in IV; the grass content was chiefly brome in both. The legume content of II was two-thirds Altaswede red clover and one-third Alsike clover, and the grasses mainly timothy. The legume content of Pasture V consisted chiefly of alfalfa, and the grass portion of about equal parts of crested and Kentucky blue grasses.

the persistence of legumes [illegible]
mainly in those lucerns, [illegible]
partially [illegible]

In the discussion of [illegible] the importance of plants [illegible]. It was seen [illegible]. The [illegible] of the [illegible] [illegible] results. The estimations of [illegible] species [illegible].

The [illegible] cutting in 19[illegible] grasses, and the [illegible] I and II, [illegible] in meadows [illegible] quantities of red and [illegible] clover in meadow III. The second cutting in the same year [illegible] grasses with a corresponding [illegible] in the [illegible]. This time a [illegible] red clover in II in the [illegible], [illegible] present only in small quantities in III; the [illegible] was entirely grass in [illegible]. The legumes [illegible] two-thirds alsike and red clover and one-third [illegible], and the grasses mainly timothy. The legume [illegible] meadow V consisted entirely of [illegible], and [illegible] grasses of [illegible] grasses.

The 1933 data point to somewhat different results. The legume content was quite low in the spring, but increased rapidly until in the third cutting it greatly exceeded the grass portion, except in Pastures II and IV. In Pasture II a marked increase in legume content was shown in the second cutting, but a decrease had again occurred by the third cutting. A similar trend was evidenced in IV, but here the quantities of legumes present were very slight. The legume content of the herbage of the first cutting was reduced to 4 percent with a corresponding increase to 96 percent in grass content in Pasture I; the former consisted chiefly of alfalfa and the latter mainly of brome grass. In Pasture II the percentage of legumes was 4.1 and consisted of about equal parts of Altaswede red clover and Alsike clover; the grass content was about 80 percent timothy and 20 percent western rye grass. Pasture IV consisted of a trace of legumes only (entirely Dutch clover), 2.2 percent weeds and 97.8 percent grasses; the grass portion was composed of 70 percent brome grass, 25 percent Kentucky blue grass and 5 percent western rye grass, on the average (the percentages of the individual species are estimations). Pasture V gave 32.5 percent legume and 67.5 percent grass in the first cutting; the former consisted of alfalfa only (trace of Dutch) and the latter of 65 percent Kentucky blue grass and the rest crested wheat grass.

[illegible] the larger [illegible] readily [illegible] green cutting, [illegible] a marked increase [illegible] cutting, [illegible] cutting. A [illegible] The [illegible] a percent with a [illegible] only (entirely [illegible] western [illegible] of the individual [illegible] percent legumes [illegible] the former [illegible] and the latter [illegible] the most [illegible]

In the herbage of the second cut the leguminous content was seen to be increasing and the gramineous content decreasing. This increase in leguminous content continued in the herbage of the third cut, except in Pastures II and IV as previously mentioned. In the second cut of Pasture I the 51.6 percent legume was composed of 80 percent alfalfa and 20 percent of Alsike, and the 48.4 percent grass was mainly brome grass. In II the one-third legume consisted of about 68 percent Altaswede red clover and 22 percent Alsike, and the 68.8 percent grass was about 90 percent timothy and 10 percent western rye grass. Pasture IV yielded mainly grass consisting of 65 percent brome, 25 percent western rye and about 10 percent crested grasses, and 2.5 percent weeds. In Pasture V the 57 percent legume consisted entirely of alfalfa, and the 43 percent grass of 70 percent Kentucky blue grass and 30 percent crested wheat grass.

Certain interesting changes also occurred in the herbage between the second and third cuttings as revealed by analysis. In Pasture I alfalfa had increased to about 97 percent of the leguminous content with a corresponding decrease in Alsike to 3 percent; the grass portion consisted of 90 percent brome grass, 2 percent crested wheat grass and 8 percent Kentucky blue grass. In Pasture II the leguminous content, which consisted of 75 percent Altaswede and 25 percent Alsike, showed a decrease with a corresponding

In the passage of the second and third transition period [illegible] from the grassland [illegible] community, [illegible] changes [illegible] the [illegible] of the [illegible] and [illegible] increasing percentages. In the second year of Figure I the 12.1 percent [illegible] had increased to 30 percent [illegible] and 31 percent of [illegible] and the [illegible] percent grasses [illegible] other. [illegible] figures consisted of about 63 percent [illegible] plants and 20 percent [illegible], and the [illegible] 8.4 [illegible] of [illegible] and 10 percent [illegible] other. Figure 17 [illegible] of [illegible] percent grasses, 65 percent [illegible] the [illegible] in [illegible] grasses, and 5.5 percent [illegible]. In Figure 6 [illegible] 32 percent [illegible] of [illegible], and [illegible] percent [illegible] of 75 percent [illegible] grass and [illegible] percent [illegible] other grasses.

Certain interesting changes were observed in the between the second and third transition [illegible] indicated by [illegible]. In Figure 7 [illegible] 11 percent [illegible] to 3 percent. The [illegible] (15) percent [illegible] grass, 2 percent [illegible] and 4 percent [illegible] other [illegible]. [illegible] which [illegible] of 73 percent [illegible] and 11 percent [illegible].

increase in the gramineous herbage, which was composed of 97 percent timothy and 3 percent western rye grass. In Pasture IV the leguminous herbage, which was Dutch clover only, had decreased to 1 percent; the grass portion, which had increased to 98 percent, consisted of 75 percent brome grass, 23 percent Kentucky blue grass and 2 percent crested wheat grass. The weed content was 0.8 percent, which indicates a rapid decrease from the second cutting. In Pasture V the increase in the proportion of legumes was slightly less than in Pasture I. This difference is due to Alsike clover in the latter, as the former pasture contained alfalfa only. The gramineous portion consisted of about 85 percent Kentucky blue grass and 15 percent crested wheat grass.

Similar seasonal changes in the proportions of legumes and grasses is reported by Aldous (1), Fenton (12) and other investigators. The factors which were thought to be operative in causing these changes were drought and temperature extremes, biological and mechanical factors, also the nature of the plant itself. The most important factor in this connection was undoubtedly drought (27) (Rigg et al), which was very severe in its effect on the less drought resistant species, Alsike and Dutch clovers, with the result that the proportions of legumes and grasses present in the herbage were markedly altered. This was

increase [illegible]

[illegible]

[illegible]

[illegible] had decreased to 1 percent; [illegible]

and increased to [illegible] percent, [illegible]

grass. [illegible] percent [illegible]

[illegible]. The red clover was [illegible] percent [illegible]

[illegible]

[illegible] an increase in the [illegible]

slightly less than in [illegible]. This difference is due

to alsike clover in the latter, as the [illegible]

[illegible]. The [illegible]

[illegible] Kentucky blue grass and [illegible] percent [illegible]

grass.

Similar seasonal changes in the [illegible]

legumes and grasses is reported by [illegible]

and other investigators. The [illegible]

[illegible] in causing these changes [illegible]

temperature extremes, [illegible]

also the nature of the plant itself. [illegible]

[illegible] in this connection [illegible]

[illegible], which was [illegible]

[illegible] drought resistant species, [illegible]

with the result that the proportion of [illegible]

[illegible]

clearly brought out in the results. It was seen that Alsike clover decreased to very small proportions towards the end of the summer in 1933 with a simultaneous increase in the alfalfa content. Altaswede red clover gave evidence of greater drought resistance than Alsike clover. Similar decreases were also shown in the amounts of western rye and crested wheat grasses present. These grasses are perhaps more affected by plant competition and cutting than by drought. Brome appears to be quite drought resistant as it made quite a good growth even in the drier months. Kentucky blue grass, while it is not as drought resistant as brome and crested wheat grasses, nevertheless, appears to have great regenerative powers, as it made very rapid growth after each rain. Brome grass and alfalfa appear to be excellent drought resisters, and seem to form an association* with Kentucky blue grass.

Extremely low temperatures, especially in early spring, appeared to be injurious to all the clovers and alfalfa. The greatest amount of injury occurred to Dutch and Alsike clovers and the least amount to Altaswede red clover, sweet clover and alfalfa.

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* The term "association" is used here in the ecological sense. It has reference to a plant community in which less vigorous species have been eliminated by competition. The remaining species are not injured one by the other.

growing [illegible]

plants [illegible]

the soil [illegible]

in the alfalfa [illegible]

[illegible]

[illegible]

[illegible]

seeding [illegible]

[illegible]

[illegible]

alfalfa. [illegible] blue grass, [illegible]

resistant [illegible]

weeds, [illegible]

made very rapid [illegible]

alfalfa [illegible]

in [illegible]

[illegible]

[illegible] [illegible]

[illegible], the [illegible]

[illegible]

clover, sweet clover and alfalfa.

---

* The term [illegible]
[illegible]. It [illegible]
[illegible]
[illegible]. The [illegible]
one of the other.

Biological factors affecting the proportions of legumes and grasses are inter-specific competition and changes in the physiology of the plant in response to its environment. Brome grass and sweet clover made very rapid growth the second season which resulted in the creation of a microclimate* near the ground. This was undoubtedly injurious to Dutch clover. Injury from this cause was also revealed to a lesser extent by the two grasses western rye and crested wheat. Neither Kentucky blue, alfalfa nor Altaswede red clover appeared to be affected in this way.

In late summer the three grasses western rye, crested wheat and Kentucky blue, particularly the two former species, exhibited a reduced rate of growth which seriously affected their productiveness, hence reduced their contribution to the grass portion of the legume-grass ratio. Vinall and Hein (38) report that this period of reduced growth occurs in most grasses coincident with or directly after the time of the year when these plants normally produce seed. Hence, the common belief that the reduced growth rate of plants in late summer is due to drought alone appears to be erroneous. This phase of the work will be discussed more fully in the section dealing with earliness and activity of growth.

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* Tall growing plants such as brome grass and sweet clover alter the atmospheric conditions near the ground by excluding sunlight and by cutting down evaporation from the soil and plant surfaces. The dampness which results after a heavy rain in the absence of sunlight often causes decay of vegetative parts of the plant. This alteration of the atmospheric conditions near the ground has been referred to by some investigators as the formation of a micro-climate.

[illegible]

legumes and grasses [illegible]

element in the physiology of the plant [illegible]

environment. [illegible]

[illegible]

[illegible]

[illegible] late summer [illegible]

[illegible] exhibited a [illegible]

[illegible] vegetative [illegible]

[illegible] to the grass [illegible]

[illegible] and [illegible] (30) report that [illegible]

[illegible] in most [illegible]

[illegible]

[illegible] the common belief that [illegible]

[illegible] in late summer is due to [illegible]

[illegible]. This phase of the work will be discussed [illegible]

[illegible] in the section dealing with [illegible]

[illegible]

* [illegible]

The amount of legumes present was also reduced in one or two cases as a result of crowding out by the tall growing brome grass. This is undoubtedly what took place in Pasture IV in the case of Dutch clover in 1933. The rank growth of sweet clover the previous year was undoubtedly also a contributing factor in crowding out the Dutch clover. The dominant character also of alfalfa in this regard is clearly seen in Pastures I and V. This species appears to exhibit very great and rapid regenerative powers. Even in the drier latter part of the season it seemed to grow at a normal rate, which is very important from a standpoint of production of late pasture.

Mechanical factors affecting the legume-grass ratio are: clipping, grazing, and trampling by livestock. No methods were devised to study the effect of grazing and treading by the cattle on the proportion of legumes to grasses in the herbage. However, it might be inferred that grazing is not unlike cutting in its effect on the herbage of pastures. The effect of cutting on the growth of grasses is clearly shown in the decrease of the quantities contributed by western rye and crested wheat grasses. Cutting did not seem to reduce, markedly, the quantities present of alfalfa, Altaswede red clover and Kentucky blue grass.

Seasonal productivity as shown by earliness and periods of active growth of the constituent species. It has been known for some time that certain species exhibit a more

rapid early, continuous and late growth than others; also that certain species have a period of maximum growth and a period of minimum growth (12, 13, 38), Fenton, Vinall and Hein. These phenomena have an important bearing on the productivity of pasture mixtures during different periods of the growing season. It was to throw some light on this problem that heights of plants in each pasture were measured.

The results of these height measurements of plants at intervals during the growing season (Tables XIII-XVII) indicate that, in general, the grasses are more rapid early growers than the legumes, and that brome grass is the earlier and more rapid grower in the spring and persists in a state of active growth, in spite of repeated defoliations, right up until cold weather sets in. These properties make brome an excellent pasture grass in areas of periodic drought. Next in earliness and persistency of growth, according to the data, is crested wheat grass. This species, however, is apparently not suitable in pasture mixtures, as repeated defoliations caused its rapid killing out, which was pointed out in an earlier section. Moreover, cattle avoid grazing it almost entirely, which indicates that it is quite unpalatable. Timothy is apparently the third most important grass species from a standpoint of earliness and persistency of growth. It was injured less by clipping than crested wheat grass, but it proved to be more subject to

[illegible] activity of pasture [illegible] the growing season. [illegible] that heights of grass [illegible]

The results of [illegible] in earliness [illegible] to the oats, is [illegible] caused its [illegible] in an earlier [illegible] from a [illegible]

drought. On the whole it is much to be preferred to crested wheat grass in mixtures for pastures. Kentucky blue grass, while it was not as early a producer of pasturage, as indicated by the data, it was nevertheless a very persistent grower late into the season. In periods of drought this grass appeared dry and dead, but as soon as a shower of rain came it was observed to spring up rapidly to produce green, succulent pasturage indicating its great regenerative powers. For this reason Kentucky blue grass will be seen to be a very desirable constituent of pasture (16, 22).

The legumes do not make as rapid growth in the spring as the grasses. This is clearly brought out by the data. Alfalfa is shown to make the most rapid early growth. Next to alfalfa in production of early spring growth is Dutch clover. Sweet clover is only slightly behind Dutch in earliness of growth. Alsike comes fourth and Altaswede last in this regard. In regard to persistence and continued growth alfalfa again leads, with Altaswede red clover second, Alsike clover third and Dutch clover last. Sweet clover could not be studied in regard to earliness and persistency of growth in 1933, because it is biennial only. In 1932 sweet clover was shown to have made the greatest late fall growth, greatly exceeding alfalfa. Continued rapid growth of alfalfa late into August is also reported by Vinall and Hein (38).

annually [illegible]

[illegible]

this spring, [illegible]

addition, as indicated [illegible]

very little [illegible]

throughout this period [illegible]

amount of rain [illegible]

produce great, [illegible]

representative [illegible]

will be seen to be a very important [illegible]

pasture [illegible].

The legumes [illegible]

acting as the grasses. [illegible]

areas, alfalfa is [illegible]

next to alfalfa in [illegible]

sweet clover. [illegible]

by [illegible] of [illegible]

them in this regard. [illegible]

growth alfalfa [illegible]

alfalfa clover [illegible]

would not be studied [illegible]

of growth in [illegible]

except [illegible]

growth, [illegible]

of alfalfa late into August [illegible]

[illegible] (38).

Palatability Considerations.

Palatability of constituent species as indicated by selectivity of the grazing animal. This investigation was not undertaken with the intention of providing data on the relative palatability of the various species included in the mixtures. This aspect warrants a separate study. However, in taking general notes on the pastures from time to time, it was observed that plants of certain species were grazed very closely while others were left almost untouched. This led the writer to make a few critical observations on the effect of grazing on the pastures, with a view to obtaining general information on the palatability of certain grasses and legumes.

These critical observations show that the more palatable species (those readily eaten by the cattle) were Kentucky blue grass, Dutch clover, alfalfa, Alsike clover, timothy, brome grass and Altaswede red clover, in the order named; the apparently unpalatable species (less readily eaten) were in descending order of merit, sweet clover, western rye grass and crested wheat grass. The photographs (Figures 10 and 11) afford an excellent illustration of the palatability of blue grass and the apparent unpalatability of crested wheat grass. These observations are not entirely in agreement with results reported by Stapledon (37). He found timothy and wild white clover to rank highest in palatability of the species studied by him.

CONCLUSION

The pasture investigation reported in this thesis was initiated in 1931, the object being to test, by means of botanical studies, the behavior of certain pasture mixtures to specific conditions of soil, climate and grazing.

It may be well to point out that the results obtained have not been presented with the idea that they are conclusive and demonstrate fully the phases of the investigation enunciated in the introduction. Certain of them do, however, appear to be significant and demonstrate that botanical changes have taken place resulting in a more homogeneous flora consisting of a few valuable species, namely, brome grass, Kentucky blue grass and alfalfa, in the better perennial pastures. The results also show that these species are more productive and more palatable than Alsike clover and Altaswede red clover, crested wheat grass and western rye grass.

Mixture III undoubtedly represents the better mixture. More care should be exercised in seeding brome grass, however. Seeding alfalfa a little heavier, and the inclusion of 2 pounds of Alsike clover seed per acre is suggested. Pastures I and V have been shown to be almost equal in regard to productivity and quality of herbage, with

the balance in favor of V. The condition of the soil in the latter is undoubtedly better than in the former, as the land had previously been used for hog runs, which may partly account for the difference in yield although no brome was included in the mixture. It is the opinion of the writer that about 3 pounds of brome grass seed per acre, well seeded, would effect an improvement in Pasture V. The results from Pasture II are not as indicative of high productivity and quality of pasturage as might be expected. It appears that neither Alsike nor Altaswede clovers by themselves in mixtures with grasses are desirable constituents of pastures. The need for alfalfa in the mixture was brought out in the results clearly. Also timothy becomes very fibrous and brown appearing in August unless pastured very closely. The studies on Pasture VI (this pasture was discarded after the second spring) were not indicative of significant results. Observations revealed merely that alfalfa and brome grass grow well together, and were not markedly injured by continuous grazing.

The weed flora appeared to have been reduced in all the pastures, also few weeds were observed to have gone to seed.

The most outstanding result of the investigation was, perhaps, the gradual disappearance of both western rye and crested wheat grasses, and the almost complete killing

out of Dutch clover. The contribution by these two grass species to the grass portion of the legume-grass ratio was at no time more than barely significant, indicating that their disappearance does not alter markedly the productivity of the mixtures in which they were included. Secondly, in this connection also might be cited the apparent amicable relation between brome grass, Kentucky blue grass and alfalfa. Further work the coming year may reveal undesirable effects of brome grass on alfalfa and blue grass.

ECONOMIC SIGNIFICANCE

The production of a pasture mixture or mixtures suitable to existing conditions of soil and climate in this area is obviously of great economic importance to farmers. Hitherto, no such mixture has been available to stockmen, and no work has been reported in Canada with the object of developing a suitable mixture, insofar as the writer is aware.

The practical objective of this investigation, the finding of species high in productivity, winter-hardiness and palatability, has been realized. Alfalfa, brome grass, Kentucky blue grass and timothy appear to be very desirable species in pasture mixtures, both from the standpoint of productivity and persistence. Alsike and Altaswede clovers may be included in the mixture with fair success, where

[illegible]

[illegible]

[illegible] a suitable mixture, [illegible]

The practical importance of this [illegible] finding of species high in productivity, [illegible] stability, has been realized. [illegible] Kentucky blue grass and timothy [illegible] species in pasture mixtures, [illegible] productivity and persistence. [illegible] may be included in the mixture [illegible]

conditions of soil permit, as they add bulk to the herbage, but they are more subject to drought and winter injury than the above four species. The undesirable species were: Dutch clover (undesirable because of killing out only), western rye grass and crested wheat grass. Sweet clover would seem to be a fair pasture plant for the second season.

These results are suggested as a guide in compounding mixtures for perennial pastures.

SUMMARY

1. The better seed mixtures for perennial pastures were those containing alfalfa, brome grass and Kentucky blue grass; the poorer mixtures (those of short duration) contained sweet clover and Dutch clover, but no alfalfa.

2. Dutch clover had disappeared almost completely by the beginning of the third season after seeding. This was believed to be due mainly to the shading and crowding effects of the tall growing brome grass and sweet clover.

3. Altaswede red clover had decreased less than Alsike clover. Both of them, however, showed rapid decreases in frequency. These plants, under the conditions of the experiment, were not entirely satisfactory pasture species.

This is believed to be due to their sensitivity to adverse factors of environment, e.g., drought, extremely low winter temperatures and plant competition.

4. Western rye and crested wheat grasses showed rapid decreases in their frequency from 1932 to 1933, due, probably, to injurious effect of repeated defoliations and the apparently short life duration of these species under the conditions of the experiment. Crested wheat grass, in particular, also proved to be very unpalatable. Thus it would seem that these species are not very satisfactory for pasture purposes in the Edmonton area.

5. Alfalfa, brome grass and Kentucky blue grass were shown to be good resisters to drought and defoliation injury, and may therefore be classed as good pasture species. Timothy, while it was not injured by drought and repeated defoliations, proved to be more suitable as a hay than as a pasture plant, as evidenced by its rank culm growth and its tendency towards head production.

6. Sweet clover was of value in the mixture only up to the middle of the second summer, because of its biennial habit of growth. The objectionable features of this plant for pasture purposes were its coarseness and coumarin content.

This is reflected in the [illegible] experiments of [illegible] Wagner of [illegible], D.C., [illegible], [illegible] the [illegible] Agriculture and [illegible].

4. [illegible] and [illegible] would [illegible] in their [illegible] greatly, to [illegible]. The [illegible] and conditions of the [illegible]. [illegible] particular, also proved to be [illegible]. [illegible] would seem that these [illegible] culture purposes in the [illegible].

b. [illegible], [illegible] were shown to be good [illegible] weeds, and may [illegible] grasses. Timothy, while it [illegible] and repeated cuttings, [illegible] a hay grass as a [illegible] hand growth and its [illegible].

c. Sweet clover [illegible] only up to the middle of the second season. [illegible] perennial habit of growth. [illegible] [illegible].

7. Weeds were kept well in check and appeared to be decreasing in frequency. Stinkweed was most troublesome, but even it showed a rapid decrease from year to year.

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[illegible] ... beetles and Plant Physiol[illegible] ... suggesting the investigation [illegible] ... during the course of the work, [illegible] ... in the preparation of the manuscript [illegible] ... Animal Husbandry, for [illegible] ... to be made on the [illegible] ... Department of Plant [illegible] ... and for materials [illegible] ... Mr. L. W. J. Johnson, for [illegible] ... photographs and [illegible]

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